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PILOT PLANT STUDY

ON

ELECTROSTATIC BENEFICIATION OF POTASH ORE

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* Ross Jackson is currently working at PCS Mining Cory Division.

ABSTRACT

Electrophysical properties of natural potash can be exploited for separation purposes in high intensity static fields to obtain commercial products or preconcentration. For the development of industrial processes high selectivity of charging is needed, this can be established by conditioning the mineral species, sylvite and halite, in a fluidized bed with appropriate reagents under well controlled humidity and temperature. Beneficiation of potash ore was carried out with PCS' plate and tube free-fall pilot separators in batch and continuous processing. Two different ore types, PCS Cory and PCS Rocanville Divisions' feedstocks with particle sizes up to 8 mesh, and four reagents, octanoic acid, oleic acid, salicylic acid and ammonium acetate were used. Important process parameters such as charging time, charging temperature, particle size, electrode length, and recycling are pointed out and discussed.

SOMMAIRE

Les proprietes electro-physiques naturelles de la potasse peuvent etre exploitees pour accroitre la teneur des minerais ou pour fabriquer des produits potassiques commerciaux. Des teneurs satisfaisantes peuvent etre obtenues par l'utilisation de champs electro-statiques a haute intensite. Pour le developpement de procede industriel, la preparation des minerais doit etre precise et tres selective. Le conditionnement des mineraux presents, sylvite et halite, peut se faire dans un lit fluidifie dans lequel la temperature, l'humidite et l'addition des reactifs sont bien controlees. La concentration des minerais de potasse a ete testee dans l'appareil pilote de Potash Corporation of Saskatchewan Limited (PCS). Les minerais provenant de PCS Cory Division et PCS Rocanville Division, ainsi que quatre reactifs ont ete testes. Les parametres de procede importants tel que le temps de preparation, temperature, grosseur des particules, longueur des electrodes, charge circulantes sont identifies et discutes.

1.0 INTRODUCTION

Electrostatic separation (ES) is a dry separation process which has the potential for being used for potash ore beneficiation. The benefits of a dry ES process offer themselves as an advantageous alternative from the viewpoint of environmental protection, energy conservation and cost. International Mineral & Chemical Corporation (IMC) patented the first electrostatic separation process of potash in the early 1950's which claimed effective separation after heating the feedstock at 300-700°C, and then cooling it to 100-200°C. A production unit based on this process was built at Carlsbad in New Mexico, U.S.A., but its operation was discontinued after a time due to practical difficulties. The research, development and pilot-scale work was initiated at the Potash Research Institute, Hanover[1], West Germany in 1953. The first commercial installation in Germany was in 1973/74 and it produced 2.2 million stpy in 1978. In the 1980s this is expected to be increased[2].

The ES process involves two stages:

(1) Conditioning and charging - Conditioning of the feed material with an appropriate chemical treatment of the particle surfaces in a controlled environment of temperature and humidity. This affects the properties of the surface layer at the mineral/air interface of the precise and correct structure which allows the mineral-specific electrostatic charge separation to develop. These charges, in turn, are the basis of the subsequent successful separation in an electric field.

(2) Free-fall separation - The free-fall electrostatic separators used had two parallel electrodes made of tubes or plates placed side by side. Although a rotating drum separator of Carpco design was previously used it was considered not suitable for the large throughputs required. The tube electrodes were used as they can be constantly kept clean with stationary brushes, while the cylindrical electrodes are rotating. A clean electrode surface seems to be important because a salt layer adhering to the electrode surface acts like the dielectric in a condenser, thus weakening or even cancelling the electric field in the separator gap.

In this work we report the results of pilot plant studies on the electrostatic separation of potash ore obtained from, (1) a batch operation plate separator and, (2) a continuous operation tube separator pilot plant in single and double pass processes.

Important process parameters such as reagent charging temperatures, charging time, feedstock particle size, electrode length and the effect of middling streams in a continuous two pass operation in a tube free-fall separator were presented and discussed.

Pilot runs were done with two different potash ores (from the Cory and/or Rocanville Divisions of PCS Mining), at -8, -10 and -14 Tyler mesh, and at 1 tph and 1.8 tph feed rates. A number of reagents, including octanoic acid, oleic acid, salicylic acid and ammonium acetate were used over the temperature range from 30°C to 80°C and charging time was from 2 minutes to 10 minutes. Reagent dosage was based on the optimal quantity from PCS's experimental results and/or from literature.

Several electrode lengths, a 4.4 m long plate electrode for the plate free-fall separator, and a 3.6 m/5.4 m long tube free-fall separator pilot plant were used.

Field strength was 1-2 kV/cm and 2 kV/cm for the plate and tube separators respectively.

2.0 PILOT PLANT ELECTROSTATIC SEPARATORS

There are two pilot plant electrostatic separators at the PCS Multipurpose Research Facility (MRF), the plate separator and the tube separator, which are described in the following paragraphs.

2.1 Plate Separator Pilot Plant

The plate separator is so called because the electrodes were made from a single piece of thin plate. It was originally designed and fabricated with PCS input during 1983-1984 under contract number 76-S00260 by Westinghouse R&D Center, Pittsburgh, Pennsylvania, where the system was commissioned. Some data to investigate humidity and

temperature conditions for electrostatic separation of Rocanville ore were collected. The plate separator was then shipped to PCS and erected in the MRF where it has become a routine testing facility since the middle of 1986. Fig. 1 gives a bird's-eye view of the plate separator pilot plant. The free-fall separation tower can be seen at the centre of the structure extending about eight metres from the top to the ground floor. On the top floor and right on top of the tower is the fluidized bed, and the high tension field power supply is located at the right-hand side corner. In the foreground are the Chipmunk jaw crusher and the cement mixer which are used to prepare the feed materials.

Fig. 1. Plate separator pilot plant

2.1.0 Fluidized Bed

The fluidized bed which was originally designed and manufactured by Westinghouse R&D Center was a 137 cm (54") tall rectangular 15 cm x 30 cm (6"x12") steel cylinder. It operated well but was very inconvenient and difficult to observe the quality of fluidization. To see what was going on in the fluidized bed the top cover first had to be removed, then a lamp with an extension cable had to be lowered slowly into it just at bed expansion level, while watching from the top of the fluidized bed. To overcome this inconvenience the fluidized bed was modified by shortening the bed height and furnishing larger see-through surrounding plexiglass as shown in Fig. 2, so that the state of fluidization could be seen easily during fluidization and free-fall as observed in Fig. 3.

2.1.1 Plate Electrodes

The plate electrodes were fabricated from plexiglass by Westinghouse and were originally laminated with 76 mm (3") aluminum conductor strips on one side, which deteriorated with time, and arcing occurred along the ledges where the strips were overlapped. The conductor strips were then replaced with one-piece 1.6 mm (1/16") thin aluminum sheets. The dimension of the plate is 1.1 m x 0.4 m with round corners to prevent corona discharge. Surrounding the perimeters of the plate were sleeved insulating rubber strips for edge protection and also for protection from handling and mishap (Fig. 4).

The four pairs of plate electrodes were positioned two in each of the four aluminum frame/plexiglass side units of 0.6 m x 0.9 m x 1.2 m.

Fig. 2. Plate separator - fluidized bed with see-through expansion.

Fig. 3. Plate separator - proper fluidization - less fluctuation in density, less channelling and slugging.

Fig. 4 shows two of the four pairs of electrodes secured in place. High voltage power supplied positive potential to one vertical series of plate electrodes and negative potential to the other. Shielded coaxial cable is used for electrical contact between plates of the same series (ie. same polarity). The fluidized bed is positioned on top of the platform with its overflow duct extending through the aluminum plate used to seal the top of the separation tower. A gasket and flange at the bottom of the overflow duct sealed the air space between it and the aluminum top plate. The heating coil was imbedded in the chamber and air was heated up while passing through.

2.1.2 Dehumidification System

Dry air is one of the most important process parameters in ES processes particularly in the very high-humidity summer months. The moisture content air which fluidizes the reagentized ore in the fluidized bed has to be controlled under an appropriate level, prior to blowing into the fluidized bed where the sylvite and halite are charged. To establish this, a dehumidification system supplied by Cargocaire was installed and has been operated since 1983 as shown in Fig. 5. Fig. 5(a) illustrates the operation principle of the Cargocaire dehumidification system; the Honeycombe desiccant wheel is a non-metallic, non-corrosive, bacterio-static, inert structure that is impregnated with an inorganic, non-granular crystalline particle solid desiccant which transfers water in the vapour phase. As the wheel slowly turns (approximately 6-10 rph), humid air passes through the flutes of the impregnated desiccant wheel which removes water vapour from the air stream. At the same time, a counter-flowing, but reactivation air stream passing through the reactivation sector of the wheel removes the moisture picked up by the desiccant ensuring continuous, controlled drying. Fig. 5(b) closes up the integrated dehumidification system and the 0.708 m^3/s (1500 SCFM) capacity blower which supplies dry air for the plate or the tube separators.

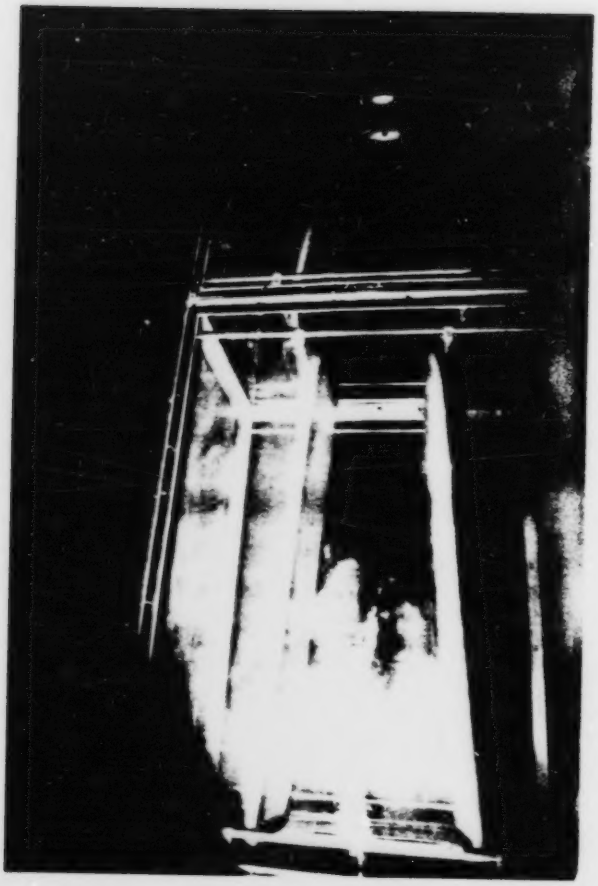

Fig. 4. Plate separator - two of four pairs of plate electrodes.

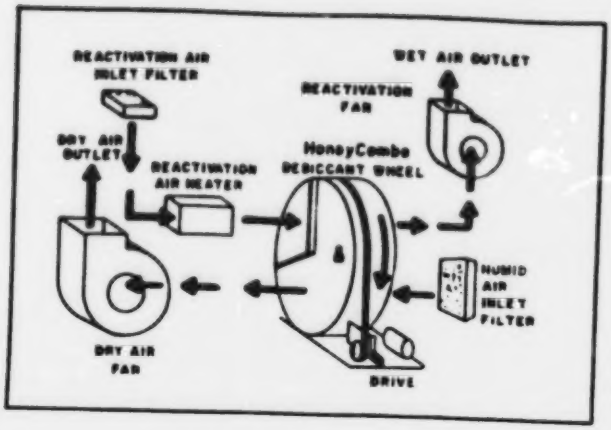

Fig. 5a. Cargocaire dehumidification - operation principle

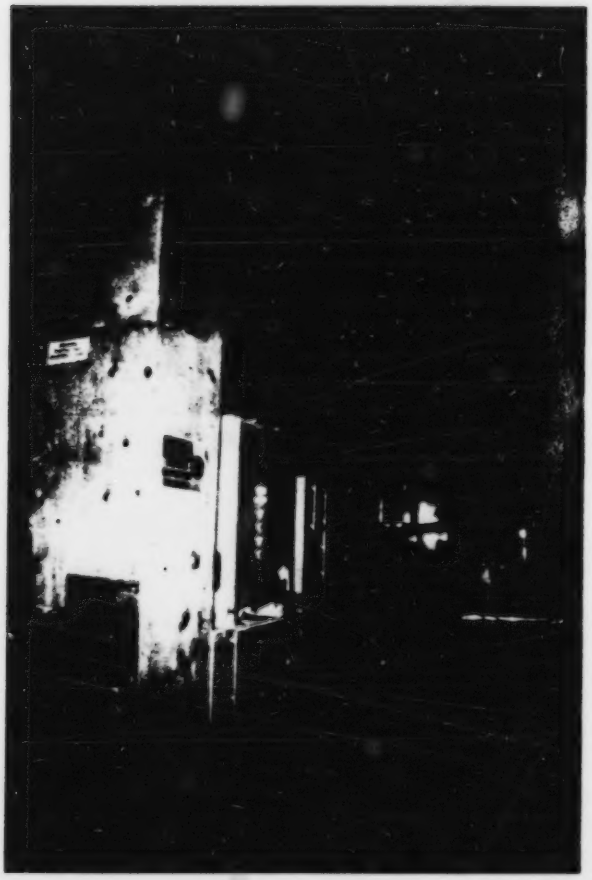

Fig.5b. PCS Pilot Plant - Cargocaire integrated dehumidification system and the air blower.

2.1.3 Feed Ore and Operation Procedures

Two types of feed were prepared from PCS Mining Cory Division ore. The normal feed was prepared from the crushed mill flotation feed by screening off the coarse (+8 mesh) and the fines (-100 mesh) fractions. The special feed was prepared from 10 to 25 cm (4 to 10 inch) potash ore lumps which were purposely hand-picked from the mill conveyor belt. These lumps, with a higher insol (water insoluble) content, were crushed by a Chipmunk jaw crusher and again screened to yield the desired fraction.

The following briefly describes the typical plate separator operating procedure: 10 kg -8 +100 mesh (or other mesh size) ore was measured and placed into a cement mixer where the ore was mixed for fifteen minutes and a sample was taken for x-ray fluorescence (XRF) and sieve analysis. An appropriate quantity of reagent was then added with either a measured syringe (for liquid reagent) or a small sponge (for solid reagent) while the ore was mixing in the mixer. The process of adding reagent took about five minutes.

The feed was ready to pour into the fluidized bed and was fluidized with humidity-controlled air from the Cargocaire dehumidification system for a pre-determined time. The charged ore was then dropped through the plate separator tower by opening the butterfly flap gate. The free-fall run time was recorded and the concentrate, middling and tail streams received in the collecting bins were weighed and split down to an appropriate quantity sample for XRF and sieve analysis.

The dimensions of the three collecting bins, determined by a series of pilot runs at Westinghouse, were 58.4 cm x 36.8 cm, 58.4 cm x 15.2 cm and 58.4 cm x 36.8 cm for concentrate, middling and tail respectively.

Figure 6 shows some ore loss in the exit air stream in the form of dust either from the original fines or from new fines generated by attrition during fluidization. Therefore, the "free-fall" feed may

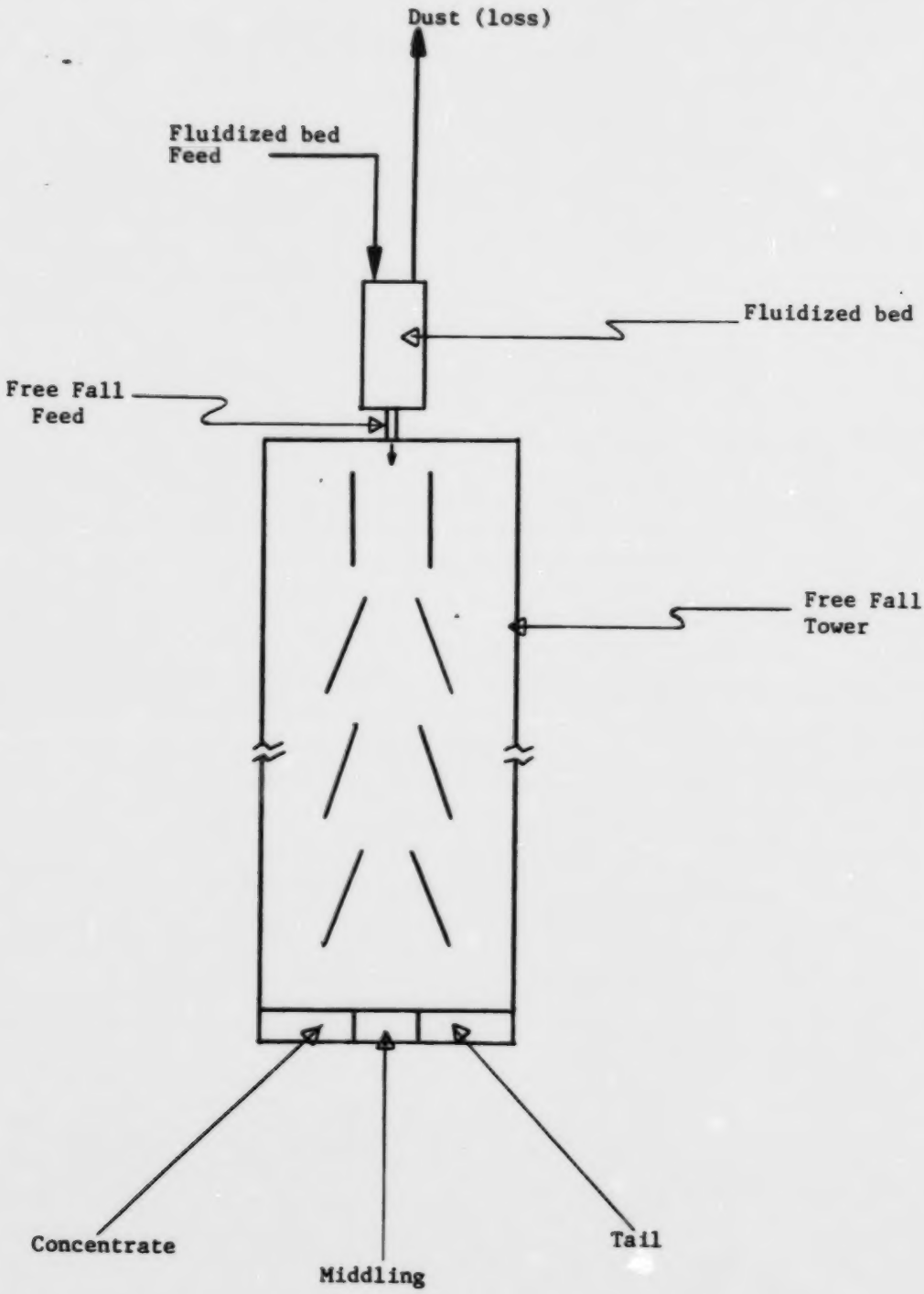

Figure 6 . PCS Plate Separator

be different from the "fluidized bed" feed (in size and grade) depending on the amount of loss.

Relative humidity was monitored by a General Eastern Dewpoint on-stream system and was backed-up by a wet/dry bulb hygrometer.

2.2 Tube Separator Pilot Plant

The tube separator pilot plant was designed for continuous operation in single-pass and multiple-pass mode. The pilot plant occupies about 6 m x 3 m floor space and is 13 m high as appears in Fig. 7. It consists of three important operation units: (1) the ore crusher and fluidized bed ore dryer, (2) the ore conditioning/reagentized drum and fluidized bed, and (3) the tube separation tower which are described in the following paragraphs.

2.2.1 Fluidized Beds for Particle Charging

Two fluidized beds, the primary fluidized bed for the first pass and the secondary fluidized bed for the second-pass, are shown in Fig. 8. The primary fluidized bed was modular in design for ease of operation change and modification. There are four replaceable baffles which divide the 20 cm x 122 cm x 30 cm (8"x48"x12") chamber into four sub-fluidized beds of equal size. The hold-up capacity of each sub-fluidized bed was determined by the "height" of the buffer (or buffers) used, and the overall fluidized bed hold-up capacity decided the particle residence time of the charging process. The air distributor plate was also sub-divided into four equivalent 203 mm x 203 mm (8"x8") plates. The hole distribution pattern and size of each of the four distributed plates can be all the same or different. There were four air distributing pipes which supplied air to each sub-fluidized bed and which could also independently control the desired flow rate to each sub-fluidized bed (Fig. 9). The secondary fluidized bed, which was about one quarter of the capacity of the primary fluidized bed, had a constant hold-up volume handling a lower feed rate from the first-pass stream. Both fluidized beds had plexiglass windows to observe the quality of fluidization during each pilot run.

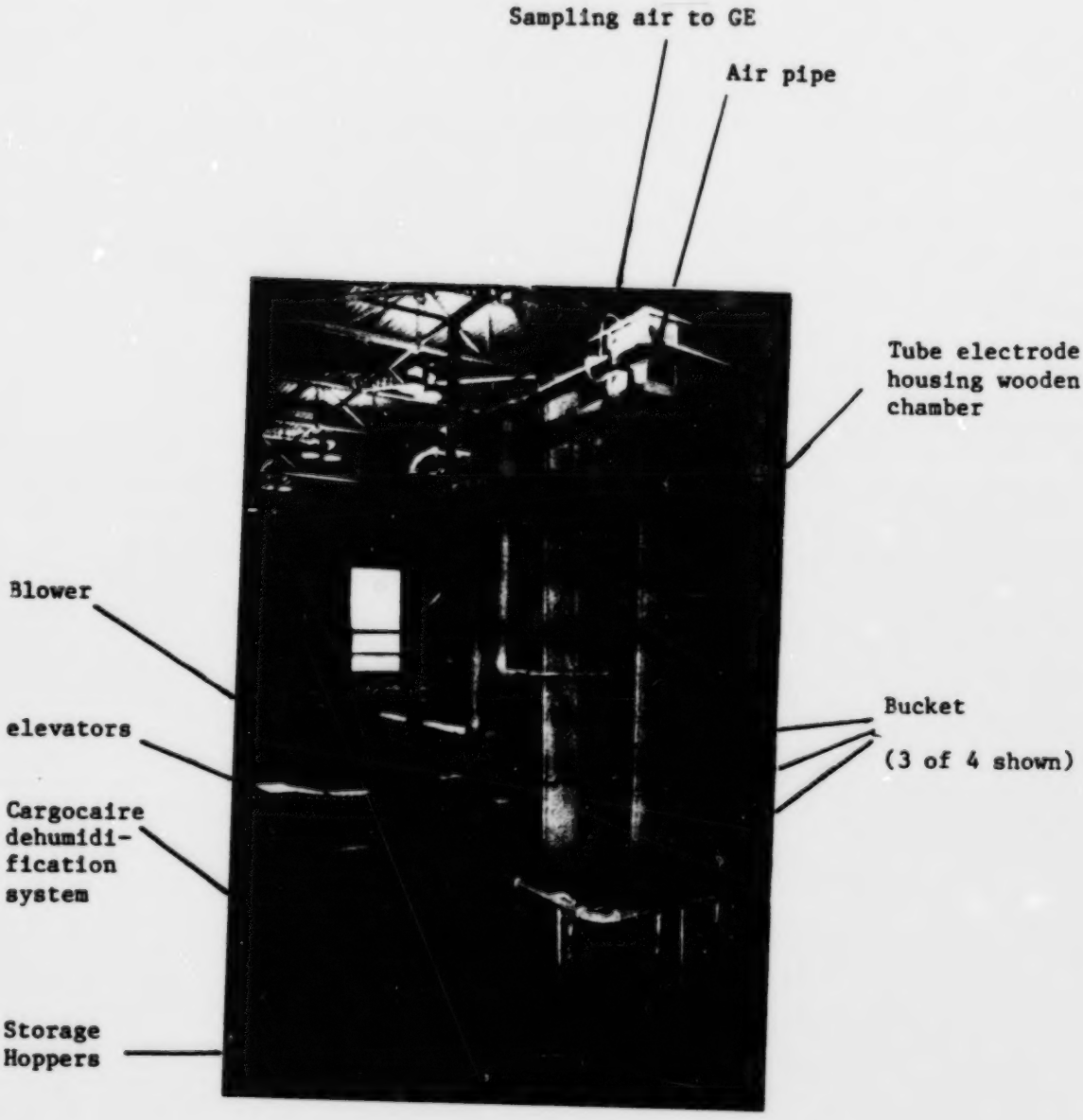

Fig. 7. A complete view of the tube separator pilot plant with 1 to 4-pass capabilities.

Fig. 8. The primary (1st-pass) and secondary (2nd-pass) fluidized bed.

Fig. 9. Fluidized bed air supplies.
Four inputs with independent control valve.

2.2.2 Tube Electrodes

The tube electrode which was designed and constructed in 1984, consisted of three sets of 1.8 m aluminum tube banks constructed in a series to make up the separator. The tube was 5.0 cm (2") in diameter as shown in Fig. 10. The electrode banks were housed in a plywood tower where three large doors could be opened to access the interior chamber for cleaning, maintenance and electrode tube replacement. The electrode tubes can be removed from/installed in their holding frame with ease and the experiment can be performed with either one, two or three banks of electrodes.

2.2.3 Feedstock and Operation Procedures

The Cory and Rocanville Division feedstocks were prepared from crushed mill flotation circuit feed by screening off the +8 mesh or +10 mesh to the desired fraction. Fig. 11 shows the tube separator two-pass circuit, and operation procedures were as follows:

After screening off the coarse fraction (in some runs the fines were also screened off) the feed was placed in a 1.5 tonne bin and passed through the fluidized bed dryer. The dried feed was then delivered to a weigh scale which fed and controlled a pre-set feed rate to the separator. On top of the weigh belt was a Quadra-beam II on-stream moisture analyzer which continuously monitored the level of moisture of the dried feed. The dried ore was then fed to a reagentizing drum mixer located on the top floor of the structure via a bucket elevator, where a pump delivered a pre-determined rate of reagent to an air atomizer which misted the reagent into the mixing drum mixer where the contacts between reagent mist and ore particles took place. The reagentized ore particles which flowed to the primary fluidized bed were fluidized and charged with humidity-controlled air supplied from the Cargocaire dehumidification system. The charged ore particles then free-fell through the electrode separator where separation took place. The concentrate, middling and tails

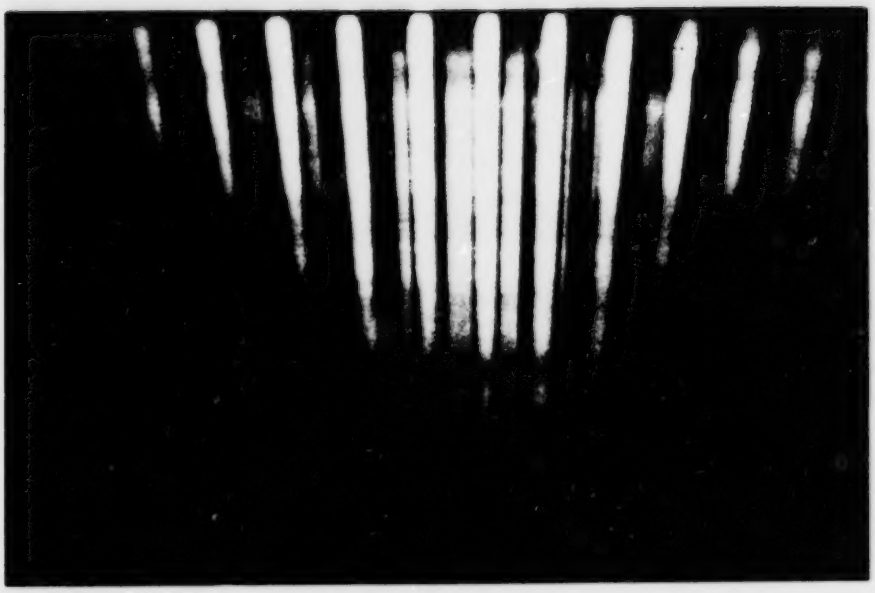

Fig. 10. One of the three tube electrode bands.

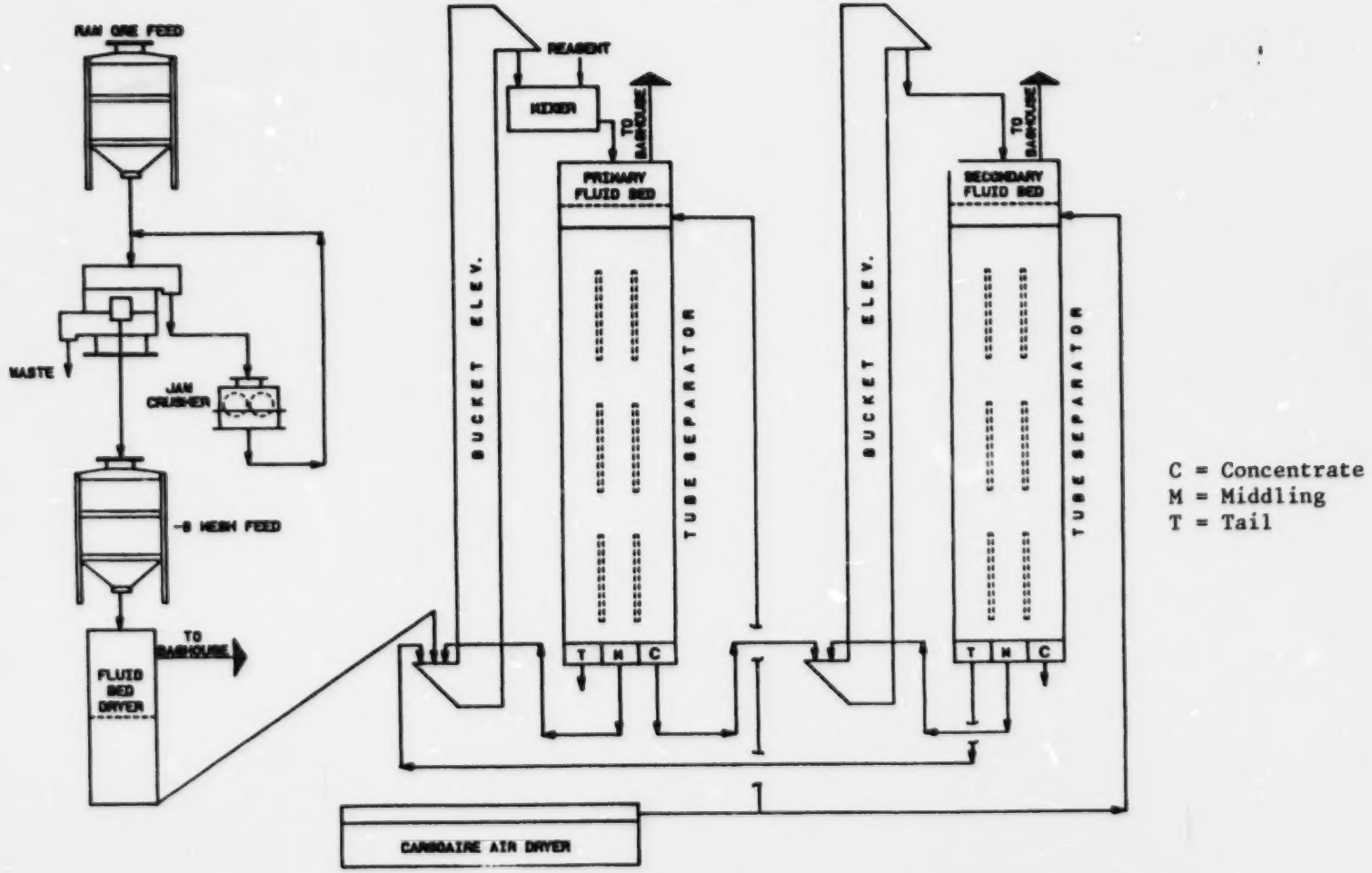

Fig. 11. PCS tube separator two-pass circuit

were either collected into storage bins or recycled or fed to the second-pass fluidized bed via the discharge handling auger system as shown in Fig. 12. Samples of concentrate, middling and tails streams were taken periodically throughout the pilot run for flowrate, XRF and sieve analysis.

3.0 RESULTS AND DISCUSSION

There were 22 batchwise pilot runs, divided into 3 sets, with the plate free-fall separator; 3 continuous single-pass pilot runs; and 11 continuous two-pass pilot runs with the tube free-fall separator, which are discussed in the following paragraphs.

3.1 Plate Free-Fall Separator

As the halite and sylvite have similar surface characteristics at the normal state, the electrostatic separation of sylvite/halite is virtually impossible unless the surface properties of the sylvite/halite particles are modified by specific inorganic and/or organic charge-control chemical reagents under carefully controlled conditions of humidity, temperature and time. This section presents test results obtained from the plate free-fall separator.

Table 1 presents the experimental program and pilot run numbers designed to evaluate the performance of four reagents from 30°C to 80°C charging temperature, 2 to 10 minutes charging time, -8+100 mesh and -14+100 mesh Cory feedstock, and the electrode configuration shown in Fig. 13.

The total 22 pilot runs with the plate free-fall separator were divided into three sets: Set-I kept charging time constant while the conditioning temperature varied from 30°C to 80°C. In Set-II, the charging temperature was kept constant at 60°C while the charging time varied from 2 min. to 10 min. In Set-III, the charging time and temperature were kept constant at 6 minutes and 60°C while the feedstock was changed from -8+100 mesh to -14+100 mesh.

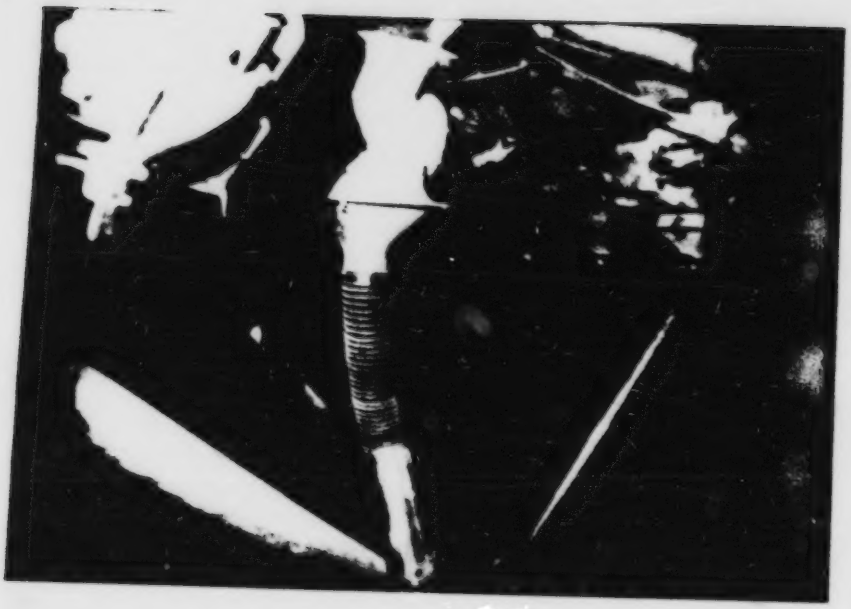

Fig. 12. PCS tube separator-concentrate, middling and tail streams of the first-pass and second-pass discharge handling system.

TABLE 1. Experimental Program for Reagents, Charging Temperature, Charging Time and Feedstock Particle Size - Run Number Designation and Type Performed*

Parameter/Set	Reagents**	Charging Temp. °C			Time min.			Feedstock Tyler mesh	Run #		
Ia	O.A.	30	60	80	2	2	5	-8+100	P 1	P 2	P 3
Ib	Ol.A.	30	60	80	2	2	5	"	P 4	P 5	P 6
Ic	S.A.	30	60	80	2	2	5	"	P 7	P 8	P 9
Id	A.A.	30	60	80	2	2	5	"	P10	P11	P12
IIa	O.A.		60		2	6	10	-8+100	P 2	P13	P14
IIb	Ol.A.		60		2	6	10	"	P 5	P15	P16
IIc	S.A.		60		2	6	10	"	P 8	P19	P20
IId	A.A.		60		2	6	10	"	P11	P17	P18
III	O.A.		60			6		-8+100		P13	
	O.A.		60			6		-14+100		P21	
	A.A.		60			6		-8+100		P17	
	A.A.		60			6		-14+100		P22	

* Plate electrode configuration 1 (Fig. 13) was used for all runs.

** Key to Reagent Abbreviations:

O.A. - Octanoic acid
Ol.A. - Oleic acid
S.A. - Salicylic acid
A.A. - Ammonium acetate

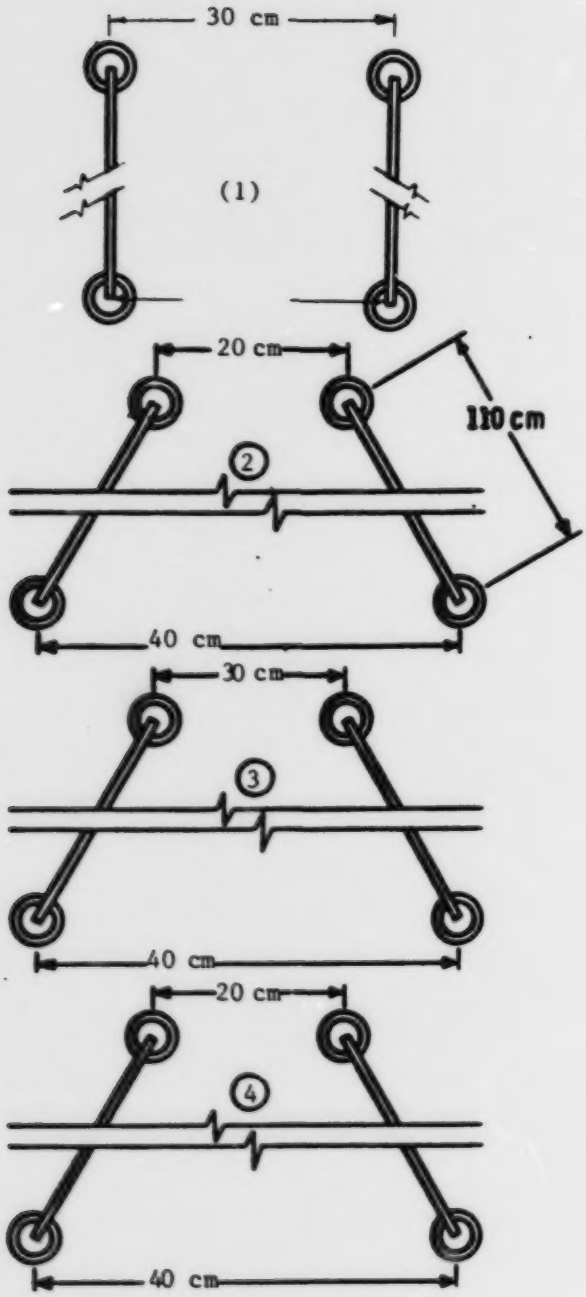

Figure 13. PCS Plate Separator - Plate Electrodes Configuration 1.

The four reagents, octanoic acid, oleic acid, salicylic acid and ammonium acetate, were chosen and used in these pilot runs. The first reagent, octanoic acid, has been used for PCS ES testing since 1982 and is considered as a reference for comparing new reagents. A derivative alkali metal salt of oleic acid, trademark Pamak 4, was used in studies at the University of Cagliari, Italy(3), and was claimed to have good selective charged property. As the Pamak 4 could not be found during the testing period, oleic acid was used instead as the second reagent. The third reagent was salicylic acid which was used by the Kali und Salz Company in their full-scale operation. Ammonium acetate was used as the fourth reagent because of the capability of removing salt and clay from sylvite in some potash feedstock(4).

3.1.1 Grade, Yield, Recovery and Particle Size Distribution

A. Feed = Concentrate + Middling + Tail

For each pilot run, the concentrate, middling and tail streams were first weighed and then samples were assayed by XRF* for percentage KCl, NaCl, Carnallite and insol (abbreviation for water insoluble) and sieved by standard Rotap for particle size distribution.

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* The PCS pilot procedure for analysis of the components of potash ore samples is included in Appendix 2.

Table 2 summarizes the raw and calculated data of run P1 obtained from the free-fall plate separator. Grade of free-fall feed, (Feed 2), yield and recovery of the concentrate, and middling and tail streams were calculated excluding the loss in the form of dust during fluidization. Data of the other pilot runs P2 to P22 appear in Appendix 1.

TABLE 2. PCS Plate Free-fall Separator - Run # P1

Parameters: Reagent : lg/10kg Octanoic acid; Temperature C : 30.00; Humidity % : 13.00; Charging time s : 120.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.06	2.75	4.65	1.66	0.94
Yield %		100.00	30.35	51.32	18.32	
Kcl %	34.15	31.99	35.85	32.54	24.03	
Nacl %	54.42	58.17	54.15	57.82	65.79	
Insol %	6.10	5.69	5.91	5.52	5.79	
Carn. %	0.50 ±	0.50 ±	0.50 ±	0.50 ±	0.50 ±	
		% RECOVERY				
Kcl		100.00	34.02	52.21	13.77	
Nacl		100.00	28.26	51.02	20.72	
Insol		100.00	31.54	49.81	18.65	
Carn.		100.00	32.17	49.25	18.58	

B. System : FEED = CONCENTRATION + TAIL

	Data calculated by combining conc.& middling as new CONCENTRATE			Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	81.68	18.32	30.35	69.65
Kcl %	31.99	33.77	24.03	35.85	30.30
Nacl %	58.17	56.46	65.79	54.15	59.92
Insol %	5.69	5.66	5.79	5.91	5.59
Carn. %	0.50 ±	0.50 ±	0.50 ±	0.50 ±	0.50 ±
Kcl Recovery %		86.23	13.77	34.02	65.98
Separation Eff. %		6.70		5.39	

* Feed2 = Free-fall feed

For particle size distribution, cumulative distribution is reported wherever it is necessary. However, to present a group of particle size distributions of a process stream in a simple and concise manner, the particle mean (a measure of central tendency) and standard deviation (a measure of spreading of a size distribution) were calculated as shown in Table 3

TABLE 3. Calculation of Particle Mean and Standard Deviation

Tyler, mesh	Sieve Opening mm low	high	dx	Average Size x mm	% in range dp feed	% / mm dp/dx	xdp
+-100+150	0.105	0.149	0.04	0.13	1.78	40.37	
+ -65+100	0.149	0.210	0.06	0.18	3.01	49.34	0.54
+ -48+65	0.210	0.297	0.09	0.25	6.05	69.55	1.53
+ -35+48	0.297	0.420	0.12	0.36	8.76	71.18	3.14
+ -28+35	0.420	0.595	0.18	0.51	11.61	66.34	5.89
+ -20+28	0.595	0.841	0.25	0.72	13.78	56.01	9.89
+ -14+20	0.841	1.190	0.35	1.02	17.88	51.24	18.16
+ -10+14	1.190	1.680	0.49	1.44	21.48	43.84	30.82
+ -8+10	1.680	2.380	0.70	2.03	14.48	20.68	29.39
+ -6+8	2.380	3.360	0.98	2.87	0.10	0.10	0.29
					98.92	1.02	

	Feed Ore	Run P1
Particle mean(x), mm=		1.01
Std.Dev. mm=		0.59

Table 4 summarizes the particle mean and standard deviation values of feed 2, (the free-fall feed), middling and tail streams of pilot runs P1 to P22. In general, the grade, yield and recovery data (Table 2), and Tables P2 to P22 (Appendix 1), together with particle size data (Table 4), are sufficient to evaluate and compare the separation performance between pilot runs. However, using all of these data for assessing the performance of the separation process, could be difficult and tedious because the yield, grade and recovery of the middling stream are not constant values.

B. Feed = Concentrate + Tail

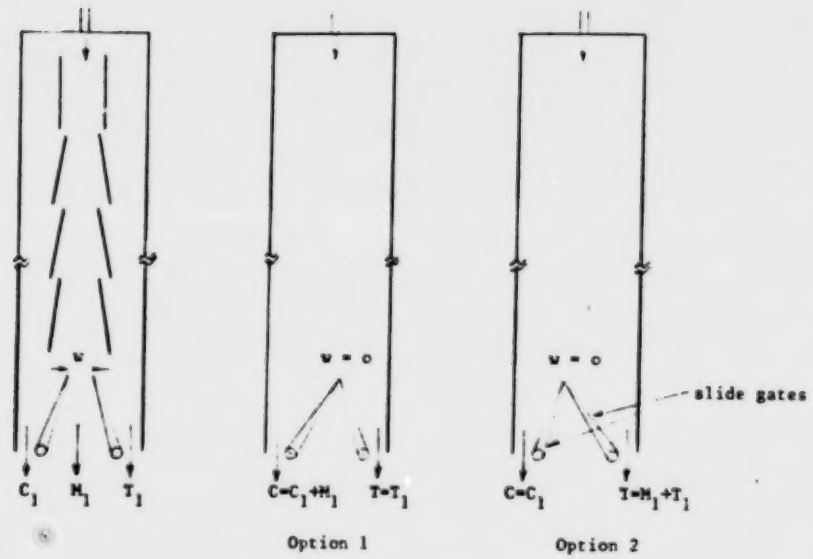
To simplify separation assessment among pilot runs and to enable a useful separation efficiency to be defined, the tertiary middle stream M1 (Fig. 14a) should be eliminated by closing up the width W defined by the position of the slide gates A and B (Fig. 14a). There are two options to eliminate the middling streams which show in Fig. 14b and Fig. 14c. In option 1 configuration, Figure 14b, the middling M1 becomes part of the "new" concentrate stream C, while in option 2 configuration, Fig. 14c, the middling M1 becomes part of the "new" tailing stream T.

Table 4 .PCS Plate free-fall separator-Summary of results - particle mean, standard deviation and %+35 mesh

Run #	Feed Size Mean (mm)	Feed Size Std.Dev. (mm)	Feed %+35Mesh	Conc. Size Mean (mm)	Conc. Size Std.Dev. (mm)	Conc. %+35Mesh	Mid. Size Mean (mm)	Mid. Size Std.Dev. (mm)	Mid. %+35Mesh	Tail Size Mean (mm)	Tail Size Std.Dev. (mm)	Tail %+35Mesh
P1	1.01	0.59	79.3	0.91	1.27	75.9	1.12	1.37	96.2	0.80	1.11	65.8
P2	1.09	0.56	87.6	1.01	1.27	81.3	1.12	1.36	89.2	1.09	1.32	89.0
P3	1.28	0.63	89.1	1.04	1.35	78.6	1.43	1.59	95.3	0.90	1.20	75.6
P4	1.06	0.60	82.3	0.94	1.24	76.7	1.30	1.51	94.3	1.01	1.30	79.8
P5	1.15	0.59	87.9	0.95	1.23	79.7	1.28	1.49	93.0	1.02	1.29	82.7
P6	1.06	0.58	84.2	0.73	1.05	61.1	1.14	1.38	88.9	1.08	1.34	86.7
P7	1.13	0.62	84.4	1.11	1.39	81.7	1.20	1.45	88.7	1.00	1.29	79.7
P8	1.13	0.62	84.9	0.91	1.23	71.9	1.20	1.45	88.3	0.98	1.26	81.5
P9	1.08	0.59	85.1	1.09	1.37	85.3	1.08	1.35	86.0	1.06	1.32	85.1
P10	1.04	0.61	81.2	0.88	1.20	70.5	1.11	1.37	85.0	0.78	1.18	68.2
P11	1.09	0.61	82.6	0.68	1.01	54.6	1.16	1.42	87.1	0.97	1.24	80.3
P12	1.14	0.61	85.9	0.76	1.09	60.6	1.22	1.45	90.1	0.91	1.19	79.0
P13	0.96	0.58	77.0	0.71	1.03	57.4	1.08	1.35	84.1	0.84	1.11	74.8
P14	0.94	0.57	76.7	0.69	0.99	57.7	1.04	1.31	83.8	0.87	1.16	75.1
P15	1.02	0.58	81.0	0.80	1.12	67.4	1.18	1.42	89.9	0.92	1.20	78.1
P16	1.08	0.59	81.8	0.72	1.05	60.0	1.18	1.43	89.6	0.98	1.26	79.9
P17	1.04	0.58	82.3	0.77	1.09	63.0	1.16	1.40	88.9	0.94	1.22	78.7
P18	1.19	0.59	88.2	0.77	1.09	63.2	1.29	1.51	92.8	0.94	1.21	79.6
P19	1.20	0.57	89.9	0.93	1.20	79.8	1.34	1.53	95.2	1.01	1.28	83.0
P20	1.28	0.56	93.1	0.93	1.19	81.5	1.41	1.58	97.4	1.09	1.33	88.4
P21	0.60	0.37	61.4	0.49	0.68	46.6	0.66	0.85	68.2	0.61	0.80	64.0
P22	0.52	0.30	54.5	0.43	0.61	39.2	0.57	0.72	60.6	0.52	0.66	54.3

Note : -8+100 mesh Cory feedstock were tested in run P1 to P20
-14+100 mesh Cory feedstock were tested in run P21 and P22

This procedure yields two output streams, concentrate and tail, for each pilot configuration and facilitates understanding of the dependence of process performance on experimental variables.



Option 1

Option 2

Fig. 14a

Fig. 14b

Fig. 14c

C_1, C = concentrate stream
M_1 = middling stream
T_1, T_2 = tail stream

Figure 14. PCS plate separator - data presentation

In addition, consider the components in each process stream to be KCl and non-KCl (which is the combination of NaCl, carnallite, insol and other impurities) binary components. Therefore, the process now has two output streams and it is a binary components system.

The grade, yield and recovery of the "new" concentrate and "new" tail of the binary outputs of the 22 pilot runs were recalculated as if the data of two new pilot runs were collected with the slide gates configuration shown in Figs. 14b and 14c and results are shown in Table 2 and Tables P2 to P22 in Appendix 1. A new term, efficiency of separation, is introduced in the next paragraph.

3.1.2 Efficiency of Separation

Separation efficiency ES is a useful parameter which characterizes the degree to which the material is separated with respect to the ratio of the increase in the useful component concentration (KCl) to the maximum possible concentration of this component in the process of electrostatic separation. The larger the ES value, the better the separation process.

The separation efficiency ES is defined and derived from recovery and grade of concentrate and tail as (7):

$$ES = \frac{(R_c - R_{c\,min}) + (R_t - R_{t\,min})}{(R_{c\,max} - R_{c\,min}) + (R_{t\,max} - R_{t\,min})} \quad (1)$$

Where:

R_c = recovery of valuable (KCl) component in an actual process

R_t = recovery of tail (non-KCl) component in an actual process

$R_{c\,min}$ = recovery of valuable component in the poorest separation (extreme case where no separation at all)

$R_{t\,min}$ = recovery of tail component in the poorest separation (extreme case where no separation at all)

$R_{c\,max}$ = recovery of valuable component in an ideal separation

$R_{t\,max}$ = recovery of tail component in an ideal separation

After substituting recovery terms at these separation conditions with % KCl grade (composition) in feed C_f, concentrate C_c, and tail C_t, the separation efficiency ES becomes:

$$ES = \frac{(C_f - C_t) \cdot (C_c - C_f)}{C_f (1-C_f) \cdot (C_c - C_t)} \quad (2)$$

Separation efficiency can also be defined as (8).

$$ES = \frac{(C_c - C_f) \cdot \frac{Y_c}{C_f}}{[(C_c - C_f) \cdot \frac{Y_c}{C_f}]} \quad (3)$$

ideal separation ($C_c = 1$, $C_t = 0$)

where Yc is the yield of the valuable component. After substituting

$$Y_c = \frac{(C_f - C_t)}{(C_c - C_t)} \text{ and } [(C_c - C_f)]\frac{Y_c}{C_f}]$$

at ideal separation conditions i.e., $C_c = 1$ and $C_t = 0$

Equation (3) turns out exactly as equation (2). Table 5 summarizes the grade, yield, recovery and separation efficiency ES of the binary outputs (concentrate/tail) and binary components (KCl/non-KCl) system. ES values were used for performance comparison, to complement the data reported on size distribution in terms of mean and standard deviation (Table 6), recovery, grade and yield.

Of the two sets of data obtained from options 1 and 2 configurations, Figs. 14b and 14C, only one set of data resulting in better separation efficiency and recovery is to be used for separation assessment. The separation efficiency ES and KCl recovery, Table 5, result of option 1 configuration are in general better than those of option 2. Therefore, the results of option 1 configuration of runs P1 to P22, and T3 to T5 (paragraph 3.2) are to be used for separator performance comparisons.

3.1.3 Effect of Process Parameters

3.1.3.1 Temperature Effect

Table 6 summarizes the pilot results of Set I which consisted of 12 runs (P1-P12) designed to observe the effect of heat treatment leading the particles to be more effectively charged. The temperatures were 30°C, 60°C and 80°C while the tribo-electric

Table 5.PCS Plate Separator-Summary of Results-
Grade, Yield,Recovery and Efficiency of Separation

BINARY COMPONENTS

		New Conc.=Conc. + Mid.					New Tail.= Mid.+ Tail				
		% KCL		CONC.			% KCL		CONC.		
Run #	Feed	Conc.	tail	%Yield	% Rec.	% Sep.eff	Conc.	tail	%Yield	% Rec.	% Sep.eff
P1	31.99	33.77	24.03	81.68	86.23	6.70	35.85	30.30	30.35	34.02	5.39
P2	35.69	39.59	23.18	76.21	84.55	12.96	45.30	33.16	20.80	26.40	8.71
P3	36.59	39.36	20.53	85.32	91.76	10.17	47.75	33.89	19.51	25.45	9.38
P4	35.68	37.17	33.27	61.96	64.47	4.01	36.81	35.04	36.48	37.59	1.79
P5	35.80	40.47	20.08	77.11	87.16	15.65	48.39	32.65	20.00	27.03	10.96
P6	35.86	39.21	24.31	77.51	84.75	11.29	44.21	34.34	15.39	18.98	5.59
P7	35.03	35.41	24.03	75.77	76.58	1.57	48.39	33.45	30.29	41.83	6.22
P8	36.36	38.66	17.99	88.89	94.50	8.81	50.02	33.67	16.50	22.70	9.73
P9	36.00	37.78	18.00	90.99	95.49	7.04	49.74	33.87	13.41	18.53	8.00
P10	36.02	36.34	33.28	89.64	90.43	1.23	43.00	34.89	14.02	16.62	4.22
P11	36.72	38.59	19.43	90.22	94.82	7.28	58.14	33.99	11.30	17.90	10.42
P12	36.60	38.80	14.46	90.94	96.42	8.64	60.90	33.65	10.81	17.99	11.32
P13	35.96	40.59	11.23	84.25	95.08	16.91	60.43	29.42	21.09	35.44	22.41
P14	35.18	42.51	14.12	74.17	89.63	23.85	56.88	30.36	18.16	29.36	17.28
P15	34.06	40.34	10.24	79.13	93.73	22.13	53.77	26.18	28.56	45.08	25.06
P16	36.15	39.86	17.15	83.67	92.25	13.44	48.85	33.87	15.21	20.55	8.37
P17	35.96	42.45	14.27	76.97	90.86	21.69	54.28	32.34	16.49	24.89	13.12
P18	38.55	41.97	18.42	85.48	93.06	12.34	51.86	37.22	9.09	12.23	5.11
P19	38.79	44.30	10.36	83.76	95.66	19.44	53.18	34.87	21.40	29.35	12.98
P20	38.34	41.87	15.49	86.62	94.60	12.93	48.21	36.04	18.91	23.78	7.89
P21	47.17	65.51	15.76	63.14	87.68	46.46	79.45	36.82	24.29	40.91	31.46
P22	46.49	58.71	27.01	61.46	77.61	30.18	71.37	41.21	17.52	26.89	17.52

charging time was kept constant at 2 minutes, except for the charging times of runs P3, P6 and P12 which were 5 minutes instead of 2 minutes because of the cause of heater capability. Table 6 shows that except for run P1, the grade (%KCl) and mean particle size of feedstocks were quite uniform. The separation efficiency was generally low and the average recovery (KCl) was 83.7%. Comparing separation efficiency ES in each experimental set, it appeared that 60°C performed best for octanoic acid, oleic acid and salicylic acid, while the ES value appeared slightly better at 80°C than at 60°C for ammonium acetate. For particle size distributions, as expected, the middling streams

TABLE 6. Summary of Set 1 Results - Heat-treatment Effect at 2 Minutes Charging Times

Exp. Set	Reagent	Treated Temp.C	Run #	Feed %Kcl	% Sep.eff	Mean particle size as Feed	Conc.	Mid.	Tail
Ia	O.A.	30	P1	31.99	6.7	1.0	.9	1.4	.8
		60	P2	35.69	13.0	1.1	1.0	1.4	1.1
		80	P3	36.59	10.2	1.3	1.0	1.6	.9
Ib	Ol.A.	30	P4	35.68	4.0	1.1	.9	1.5	1.0
		60	P5	35.80	15.7	1.2	.9	1.5	1.0
		80	P6	35.86	11.3	1.1	.7	1.4	1.1
Ic	S.A.	30	P7	35.03	1.6	1.1	1.1	1.5	1.0
		60	P8	36.36	8.8	1.1	.9	1.5	1.0
		80	P9	36.00	7.0	1.1	1.1	1.4	1.1
Id	A.A.	30	P10	36.02	1.2	1.0	.9	1.3	.8
		60	P11	36.72	7.3	1.1	.7	1.4	1.0
		80	P12	36.60	8.6	1.1	.8	1.5	.9
Average standard deviation, 1σ						0.6	1.2	1.4	1.3

O.A. - Octanoic acid
Ol.A. - Oleic acid
S.A. - Salicylic acid
A.A. - Ammonium acetate

showed the coarsest in mean particle size, while the concentrate and tails streams showed equal or slightly finer in mean particle size with regard to the feed stream (Table 6). However, the average standard deviations of the concentrate/middling/tails were twice or more than that of the feed stream.

3.1.3.2 Charging Time and Reagent Effect

Table 7 summarizes the pilot results of Set II which consisted of 12 runs (P2, P5, P8, P11, P13 to P20) designed to study the effect of charging time at 2, 6 and 10 minutes, while keeping the heat treated temperature constant at 60°C. Again, the separation efficiency ES was generally low and peaked at 6 minutes charging time for oleic acid, salicylic acid and ammonium acetate, while octanoic acid appeared to have a better performance at 10 minutes.

TABLE 7. Summary of Set II Results - Reagents and Charging Time Effect at 60°C Temperature Heat-treatment

Exp. Set	Reagent	Run #	Charging Time Min.	Feed %Kcl	% Sep.eff	Mean particle size on Feed	Conc.	Mid.	Tail
IIa	O.A.	P 2	2	35.69	13.0	1.1	1.0	1.1	1.1
		P13	6	35.96	16.9	1.0	0.7	1.1	0.8
		P14	10	35.18	23.9	0.9	0.7	1.0	0.9
IIb	Ol.A.	P 5	2	35.80	15.7	1.2	1.0	1.3	1.0
		P15	6	34.06	22.1	1.0	0.8	1.2	0.9
		P16	10	36.15	13.4	1.1	0.7	1.2	1.0
IIc	S.A.	P 8	2	36.36	8.8	1.1	0.9	1.2	1.0
		P19	6	38.79	19.4	1.2	0.9	1.3	1.0
		P20	10	38.34	12.9	1.3	0.9	1.4	1.1
IId	A.A.	P11	2	36.72	7.3	1.1	0.7	1.2	1.0
		P17	6	35.96	21.7	1.0	0.8	1.2	0.9
		P18	10	38.55	12.3	1.2	0.8	1.3	0.9
	Average standard deviation, 1σ					0.6	1.1	1.4	1.2

O.A. - Octanoic acid
Ol.A.- Oleic acid
S.A. - Salicylic acid
A.A. - Ammonium acetate

Triboelectrification is a complex charging process, particularly for non-conductors such as sylvite and halite particles with the addition of chemical reagent. The mechanism of charge accumulation and depletion on particles is a dynamic process and perhaps can be described by one of the three charging modes as in Fig. 15.

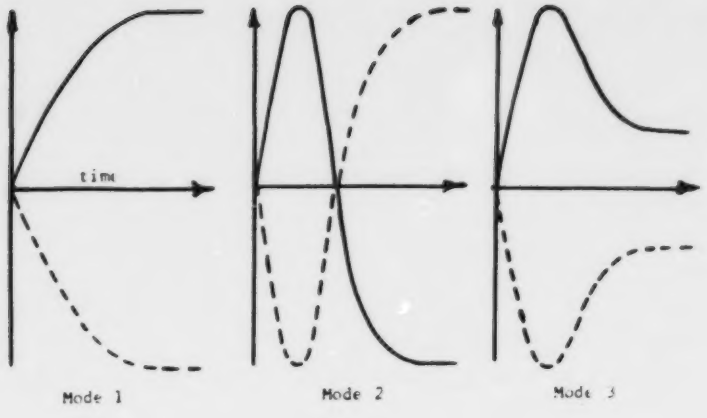


Fig. 15. Contact charging modes

In mode 1 charging increased to a saturation level with time and was always unipolar. In mode 2 charging increased with time to a maximum value and then decreased and changed polarity to eventually attain an equilibrium level. In mode 3 charging increased with time to a maximum and then decreased to an equilibrium level and was always unipolar. Mode 3 charging mechanism appeared adequate to apply to oleic acid, salicylic acid and ammonium acetate where the ES value as a charging index, increased and maximized somewhere between 4 to 6 minutes time, and then decreased at 10 minutes time (Fig. 7). For octanoic acid, mode 1 charging mechanism might be applicable; however, more test results at 6-10 minutes time are needed to verify the charging mechanism.

3.1.3.3 Feedstock Particle Size

Table 8 summarizes the pilot results of Set III which consisted of 4 runs (P13, P21, P17, P22) designed to observe the effect of feedstock particle size. The runs were performed at 60°C and 6 minutes charging time, the best operating conditions obtained from Set II results with octanoic acid and ammonium acetate.

Data show that the feedstock of runs P21/P22 prepared from -14+100 mesh Cory mill feed were much finer. The mean particle size of runs P21 and P22 was 0.6 and 0.5 mm respectively compared to 1.0 and 1.0 mm for runs P13 and P14. The %KCl of feedstock in runs P21 and P22 was also much higher as a result of screening off +14 mesh particles. As expected, the separation efficiency improved for both reagents and was almost triple with octanoic acid. The finer and better grade feedstock was the reason for better separation.

TABLE 8. Summary of Set III Results - Feedstock Particle Size Effect at 60°C Heat-treatment and 6 minutes Charging Time

Exp. Set	Reagent	Treated Temp.C	Run #	Feed %Kcl	% Sep.eff	Mean particle size mm Feed	Conc.	Mid.	Tail
* IIIa	O.A.	60	P13	35.96	16.9	1.0	0.7	1.1	0.8
		60	P21	47.17	46.5	0.6	0.5	0.7	0.6
** IIIb	A.A.	60	P17	35.96	21.7	1.0	0.8	1.2	0.9
		60	P22	46.49	30.2	0.5	0.4	0.7	0.5
			P13			0.6	1.0	1.4	1.1
			P21		Std.dev.	0.4	0.7	0.9	0.8
			P17			0.6	1.1	1.4	1.2
			P22			0.3	0.6	0.7	0.7

O.A. - Octanoic acid
A.A. - Ammonium acetate
* -8+100 Tyler mesh Cory ore
** -14+100 Tyler mesh Cory ore

3.1.4 Determination of the Optimal Middling Band

The middling stream plays an important role in the electrostatic separation process and the mass flow trapped is determined by the width of the centre collecting bin. The two pilot runs, P23 and P24, were carried out with multicollecting bins to determine the best middling width for the plate separator.

Table 9 summarizes the results of runs P23 and P24 where a set of eight identical collecting bins were used to collect ore distribution after free-fall separation. The bin dimension was 58 cm x 11.4 cm (22.75" x 4.5") and was identified as A to H (Fig. 16). In run P24, the E bin was further equally divided into two smaller sub-bins which were identified as EL and ER. Pilot runs were carried out at 60°C and 6 minutes charging time with octanoic acid at 1.7 tph feed rate.

Fig. 16 illustrates the distribution of ore collected on the eight bins. Visual observation showed that a lighter white colour appearing on A to D bins and darker red appearing on F to H bins were salt-rich (tails) and potash-rich (concentrate) ore particles, while the colour of bin E looked like that of a feed ore. Ore colour distribution across the collecting bins gave a good indication of how the separation process performed. Distribution of yield, KCl, insol, KCl/insol recovery and particle mean/standard deviation (Table 9) of bins A to H of runs P23 and P24, which are shown in Figs. 17 and 18 respectively, were discussed as follows:

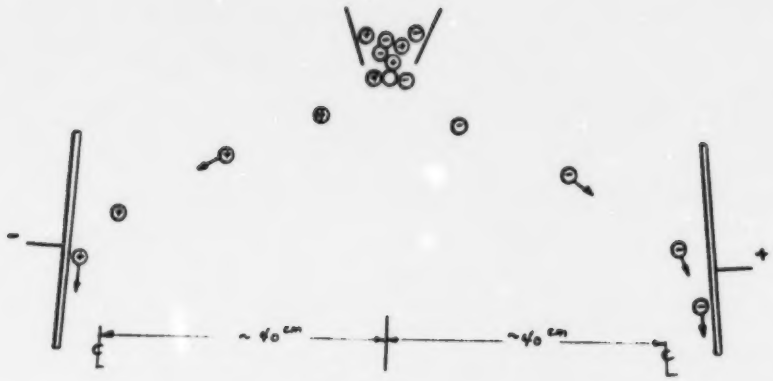
1. Yield distribution was heavily concentrated to bin E, more than 51% in run P23, and reduced to about 40% on bin EL (half size of bin E) of run P24.

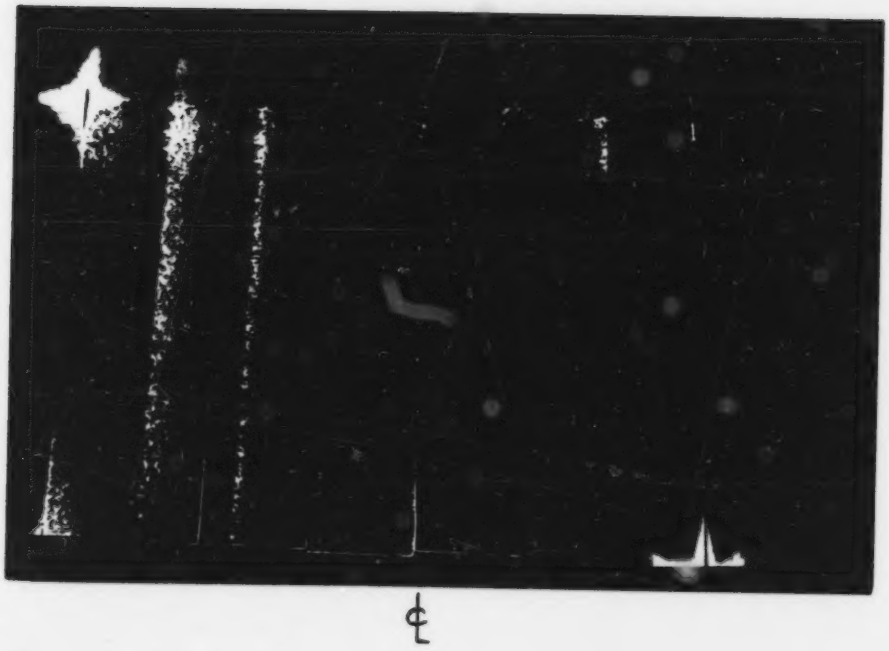
2. Percent KCl, about 17% for run P23, and 23% for run P24, distributed quite uniformly across the tailings bins (A to D), then increased to 30-35% on middlings E/EL bin, about the grade of the feedstock, while the % KCl of the concentrate bins, F to H, ranged from 50-67%.

3. Nearly 60% of KCl recovery was still in the middlings bin E. This dropped to 43% when the size of the bin E was reduced by half.

Table 9. Summary of yield, grade, Kcl/Insol recovery and mean particle size of the 8/9 collecting bins

Bin identification		A	B	C	D	E		F	G	H
					Run # P23					
Wt. g	8967.90	219.40	323.40	217.30	2535.30	4658.70		240.10	548.90	224.80
%Wt.Dist.	100.00	2.45	3.61	2.42	28.27	51.95		2.68	6.12	2.51
%Kcl	33.16	19.74	14.03	20.32	17.87	37.44		51.53	67.41	66.60
%Nacl	61.92	74.68	79.32	72.62	77.84	57.56		42.91	27.70	28.60
%Insul	3.20	3.71	4.33	4.68	2.84	3.11		4.57	3.42	3.39
%Garn.	1.53	1.78	2.16	1.28	1.28	1.50		2.62	1.99	1.92
% Kcl Recovery		1.46	1.53	1.48	15.24	58.66		4.16	12.44	5.03
% Insol Recovery		2.84	4.89	3.55	25.13	50.56		3.83	6.55	2.66
Size, Mean mm		0.82	0.68	0.71	1.04	1.12		0.60	0.60	0.85
Size, Std. mm		0.54	0.49	0.49	0.54	0.61		0.49	0.50	0.57
		A	B	C	D	EL	ER	F	G	H
					Run # p24					
Wt. g	9322.00	224.00	323.00	207.00	2395.00	4158.00	1162.00	236.00	442.00	175.00
%Wt.Dist.	100.00	2.40	3.46	2.22	25.69	44.60	12.47	2.53	4.74	1.88
%Kcl	31.53	22.92	19.89	25.99	25.57	30.53	40.96	41.20	51.64	49.69
%Nacl	62.97	68.30	70.47	65.02	69.03	65.30	53.80	50.31	38.65	41.16
%Insul	3.60	5.77	6.23	5.70	3.58	2.76	3.44	5.47	6.20	5.81
%Garn.	1.73	2.97	3.31	3.05	1.71	1.36	1.09	2.97	3.41	3.26
% Kcl Recovery		1.75	2.19	1.83	20.83	43.18	16.19	3.31	7.76	2.96
% Insol Recovery		3.85	5.99	3.51	25.53	34.18	11.90	3.84	8.16	3.03
Size, Mean mm		0.90	0.78	0.71	1.03	1.21	1.26	0.72	0.73	0.89
Size, Std. mm		0.58	0.57	0.53	0.59	0.59	0.61	0.55	0.58	0.60





Salt-rich

Potash-rich

Fig.16. PCS plate separator - distribution of -8+100 mesh Cory ore after free-fall.

4. Insol recovery distributed more to the tailings bin (A to D) than to the concentrate bin (F to H); 36.4% vs 13.0% in run P23, and 38.9% vs 26.9% in run P24, while 50.6% and 34.2% were retained in the middlings bins for runs P23 and P24 respectively.

5. The mean particle size (Fig. 18) and particle size distribution (Fig. 19) revealed that the two outermost bins, bin A of tail and bin H of concentrate, collected coarser particles than bins B and C of tail and F and G of concentrate, while the mean particle size almost symmetrically distributed with respect to bin E or EL (Fig. 18). However, the two central bins, D and E (on EL and ER for run P24) dominated most of the coarse particles.

   The coarser particles, about 0.8 mm in mean particle size, appearing on the two outermost bins A and H suggested that some coarse particles reached a reasonably charged level and were deflected across the high intensity field for a distance of about 40 cm, measuring between the centre lines of the free-fall tower and that of bin A or H. Some of these particles might be knocked down by one of the four particle's dynamics, namely: flood, shielding, dispersal and blocking. This suggests more tests should be done at a lower feed rate.

   The above observations suggest that the ore distribution after free-fall was asymmetric with respect to the free-fall centre line, as the halite always gained a significantly higher charge than that of sylvite in the charging process(3). The middling occurred at about bin E position and the width of the collecting bin might be less than 5.7 cm. This suggests more studies are necessary to obtain more data inside the bin E by further dividing it into narrower sub-bins using the current testing conditions. Such data would be useful to determine the optimal middling band for a specific separator, ore type and operating conditions.

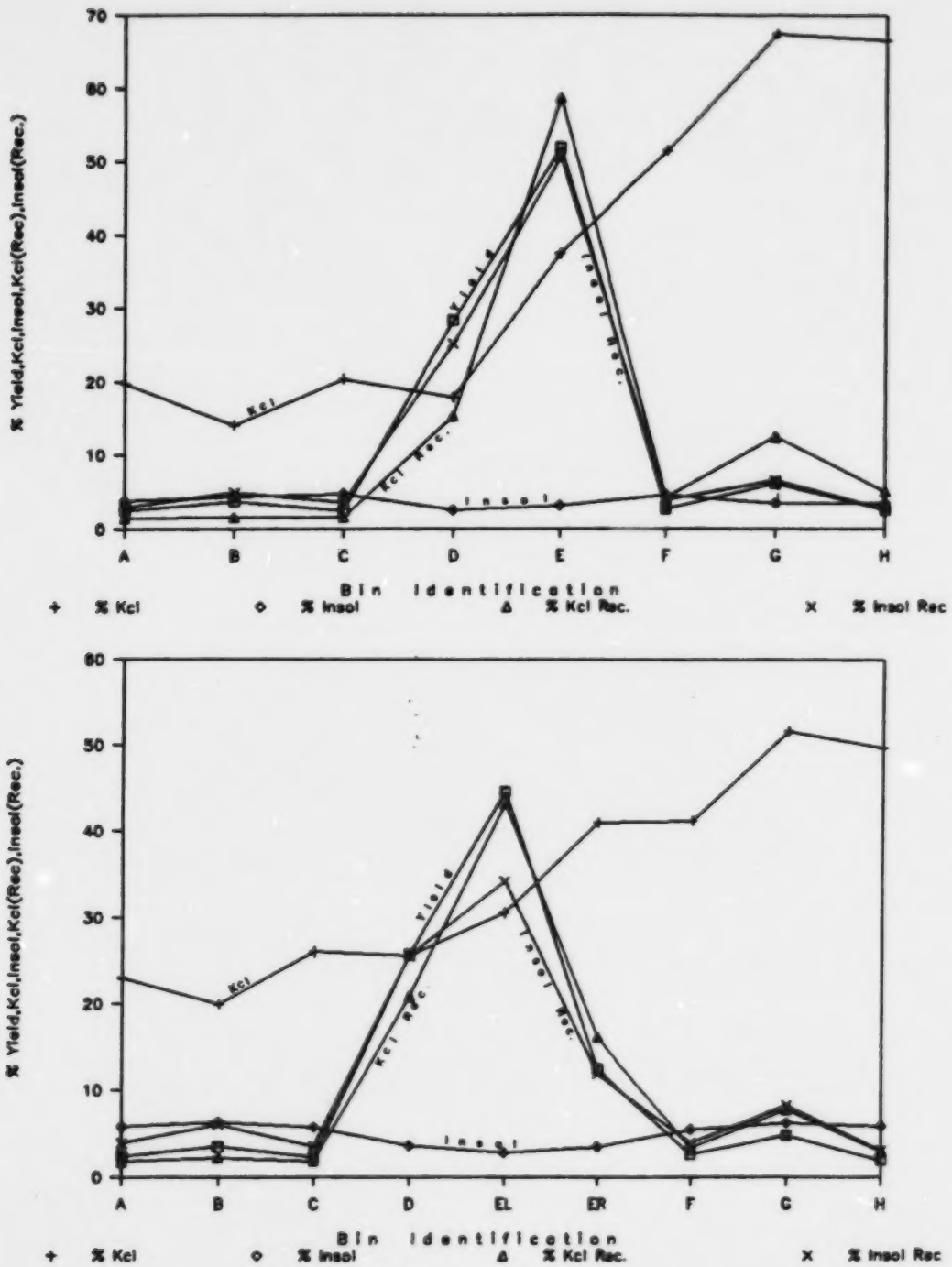


Fig.17. Distribution of yield, KCl, insol, KCl/insol recovery of runs 23/24 in 8/9 collecting bins.

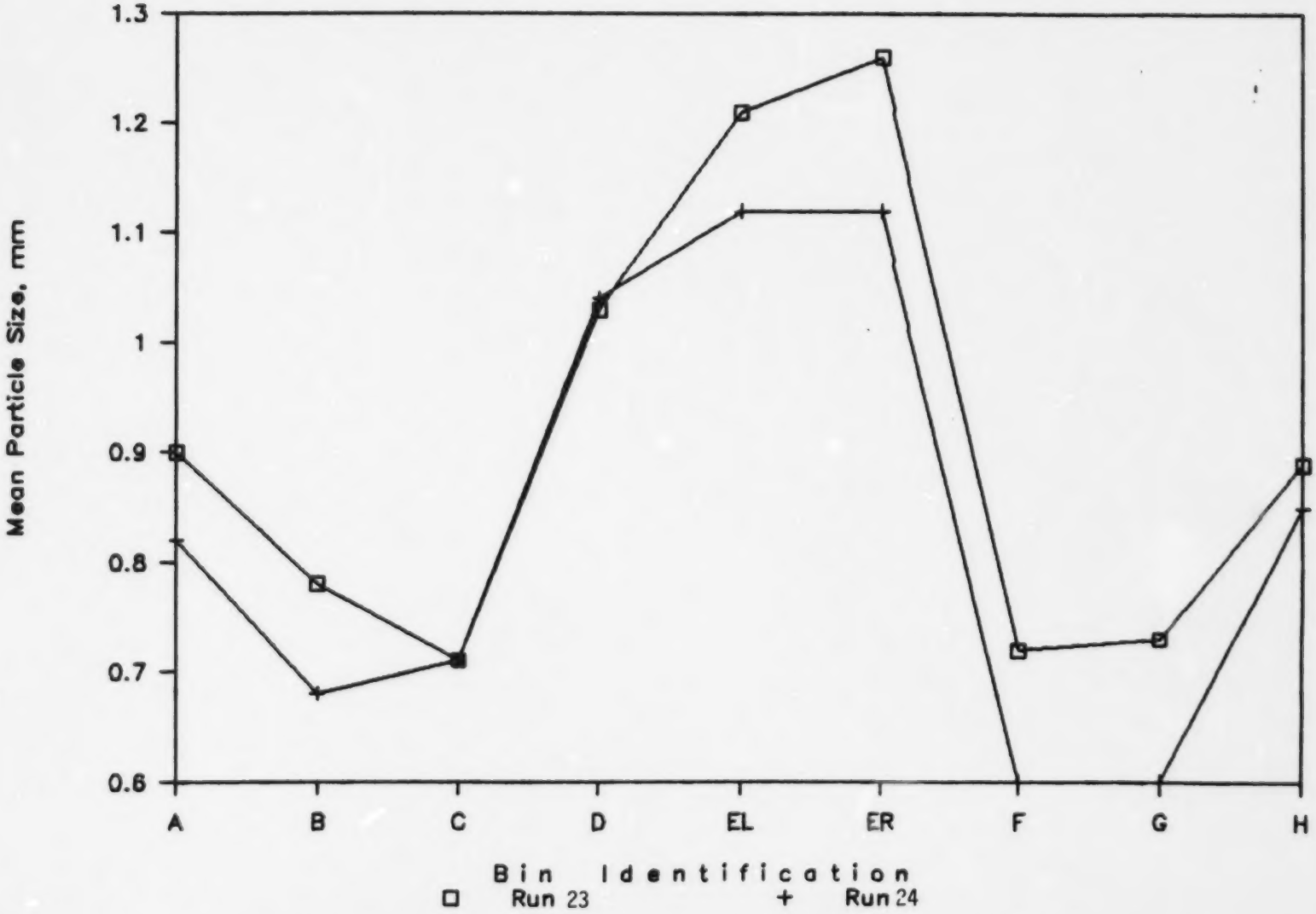


Figure 18 Distribution of particle mean and standard deviation of runs 23/24 in 8/9 collecting bins

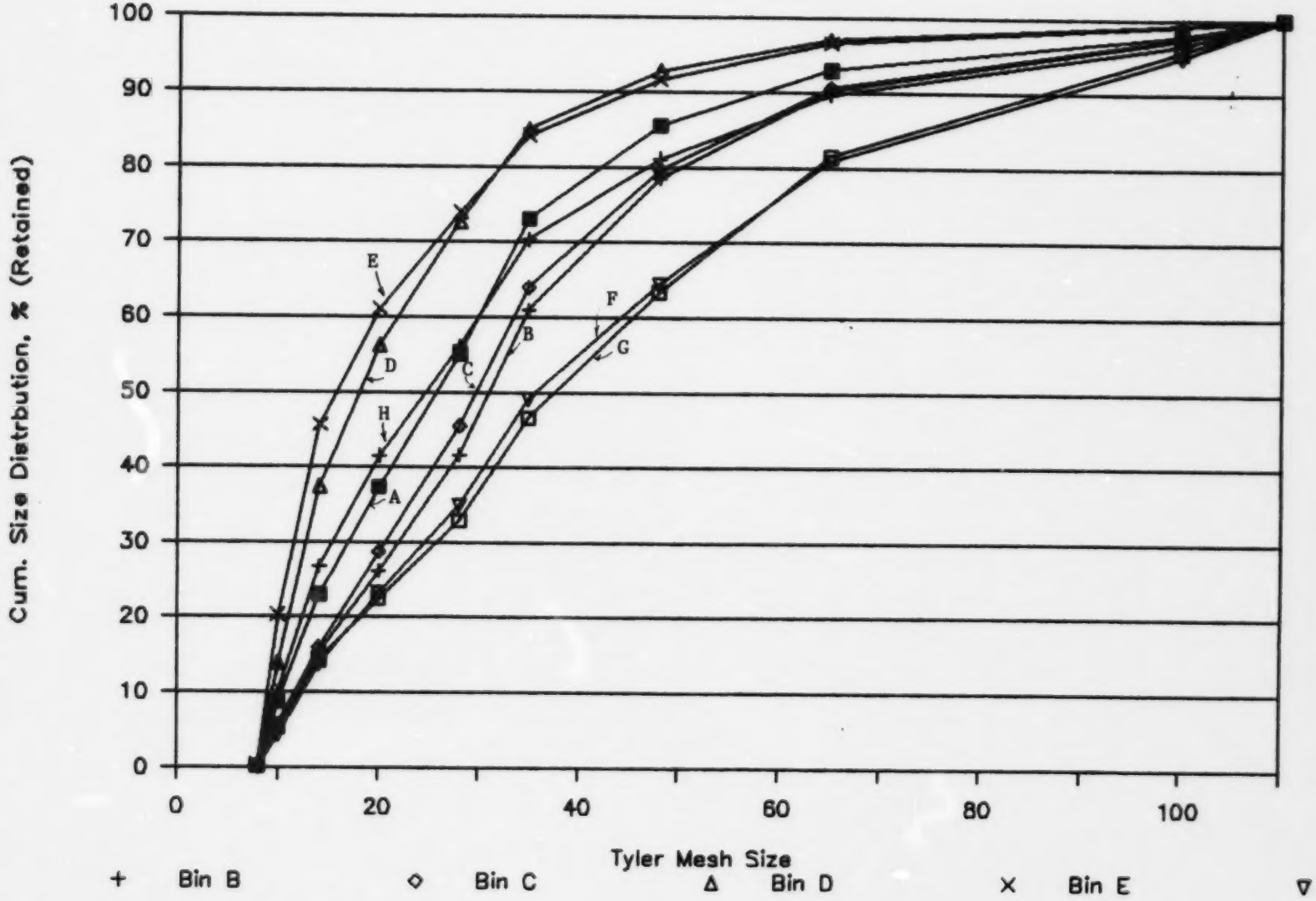


Figure 19 Comparison of particle size distribution among A - H bins (Runs 24)

3.2 Tube Separator - Results and Discussion

3.2.1 Effect of Fluidization Residence Time and Electrode Height on Separation

As it was described in 2.2, the tube free-fall separator pilot plant was designed for continuous operation in single-pass and multiple-pass modes. Table 10 shows the test condition of set Tube-1 which consists of three runs designed to observe the effect of particle charging residence time (runs T3, T4 and T5) and electrode height (runs T3, T4) on separation in single-pass continuous operation. Cory -10+100 mesh feedstock, octanoic acid reagent, and feed rate of 1.8 tph applies to all three runs.

TABLE 10. Test Conditions of Set Tube-1 (Runs T3, T4 and T5).

Run No.	Electrode Height m	Fluidized Bed Hold-up Volume m^3
T3	5.4	0.076
T4	3.6	0.076
T5	5.4	0.057

In run T3, three pairs of 1.8 m electrodes were used and the fluidized bed hold-up volume was 0.076 m^3 (2.67 ft^3). In run T4 the hold-up volume was kept the same, while the third pair of electrodes, the bottom pair, were removed to shorten the electrode height. In run T5 the hold-up volume was reduced to about 25% from 0.076 m^3 (2.67 ft^3) to 0.057 m^3 (2.00 ft^3), while the electrode height was kept the same as that of run T3.

Data of grade, yield, recovery, and particle size distribution of concentrate, middling and tail streams of runs T3-T5 are shown in Tables 11, 12, 13 and Figures 20 and 21, respectively. Again, for ease and clarity of separation assessment among these runs, the binary components and binary output system which were already discussed in 3.1.1 were used to treat these data. Yield, recovery and separation efficiency of the "new" concentrate/tails and concentrate/"new" tail streams of runs T3-T5 were calculated and tabulated in Tables 11, 12 and 13 and are also summarized in Table 14.

It was not easy to prepare large quantities of feedstock of the same grade and size distribution. Besides, the grade and size distribution of "free-fall feed" was dependent upon how the fines of the initial feed survived (being blown out) first in the fluidized bed dryer and secondly in the charging fluidized bed. Therefore, free-fall feed which was calculated from mass balance was slightly different in grade and size distribution from the initial feed. The feed grade, %KCl, of runs T3, T4 and T5 was 49.43%, 45.17% and 43.37% respectively, while its size was quite close in distribution as shown in Fig. 20a and had mean particle sizes of 0.81 mm, 0.83 mm and 0.79 mm respectively (about 20 mesh).

3.2.1.1 Effect of Fluidization Residence Time (Run T3, T5)

Table 14 shows that the run T5, which had about 25% less fluidized bed hold-up capacity and lower grade (KCl) feedstock, resulted in better separation efficiency, 35.2%, than that of run T3, 31.9%. The better separation efficiency was believed to be due to lower %KCl in the tail stream. However, the particle size distribution of run T5 appeared finer (Table 14 and Figures 20 and 21) than that of run T3, particularly on the tail stream.

Table 11 . Tube free-fall Separarator-Run # T3

Parameters		
	Electrode conf.:	Full (3 pairs)
	Reagent 1g/10kg:	Octanoic acid
	Temperature C:	40.30
	R.H. % :	5.00
	Charging time s :	180.00
	Feed rate,t/h:	1.76
	Feed size, Mesh:	-10+100

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

			Weight and XRF analysis			
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust & Spillage
Weight kg	1140.00	843.00	190.00	430.00	223.00	297.00
Yield %		100.00	22.54	51.01	26.45	
Kcl %	46.85	49.43	72.52	54.86	19.30	
Nacl %	48.07	45.70	22.39	39.35	77.80	
Insol %	3.47	3.31	3.42	4.00	1.90	
Carn. %	0.50≤	0.50≤	0.50≤	0.50≤	0.50≤	
		% R E C O V E R Y				
Kcl		100.00	33.06	56.61	10.33	
Nacl		100.00	11.04	43.92	45.04	
Insol		100.00	23.26	61.57	15.17	
Carn.		100.00	22.54	51.01	26.45	

B. System : FEED = CONCENTRATION + TAIL

	Data calculated by combining conc.& middling as new CONCENTRATE		Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	73.55	26.45	22.54	77.46
Kcl %	49.43	60.27	19.30	72.52	42.72
Nacl %	45.70	34.15	77.80	22.39	52.48
Insol %	3.31	3.82	1.90	3.42	3.28
Carn. %	0.50≤	0.50≤	0.50≤	0.50≤	0.50≤
Kcl Recovery %		89.67	10.33	33.06	66.94
Separation Eff. %		31.89		20.82	

*Feed2 = Free-fall feed

Table12 . Tube free-fall Separarator-Run # T4

Parameters		
	Electrode Conf.:	No Bottom pairs electrode
	Reagent 1g/10kg:	Octanoic acid
	Temperature C:	39.10
	R.H. % :	5.00
	Charging time s :	180.00
	Feed rate,t/h:	1.82
	Feed Size,Mesh:	-10+100

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Feed1	*Feed2	Weight and XRF analysis Conc.	Mid.	Tail	Dust & Spillage
Weight kg	1350.00	919.00	132.00	560.00	227.00	431.00
Yield %		100.00	14.36	60.94	24.70	
Kcl %	42.88	45.17	67.54	49.33	21.90	
Nacl %	51.30	50.19	27.62	45.66	74.48	
Insol %	4.41	3.32	3.27	3.82	2.12	
Carn. %	0.50≤	0.50≤	0.50≤	0.50≤	0.50≤	
		%	R E C O V E R Y			
Kcl		100.00	21.48	66.55	11.98	
Nacl		100.00	7.90	55.44	36.66	
Insol		100.00	14.14	70.09	15.77	
Carn.		100.00	14.36	60.94	24.70	

B. System : FEED = CONCENTRATION + TAIL

	Data calculated by combining conc.& middling as new CONCENTRATE Feed	Conc.	Tail	Data calculated by combining tail & middling as new TAIL Conc.	Tail
Wt. Yield %	100.00	75.30	24.70	14.36	85.64
Kcl %	45.17	52.80	21.90	67.54	41.42
Nacl %	50.19	42.22	74.48	27.62	53.97
Insol %	3.32	3.72	2.12	3.27	3.33
Carn. %	0.50≤	0.50≤	0.50≤	0.50≤	0.50≤
Kcl Recovery %		88.02	11.98	21.48	78.52
Separation Eff. %		23.21		12.97	

*Feed2 = Free-fall feed

Table 13 . Tube free-fall Separarator-Run # T5

Parameters		
	Electrode Conf.:	Full (3 pairs)
	Reagent 1g/10kg:	Octanoic acid
	Temperature C:	41.40
	R.H. % :	5.00
	Charging time s :	120.00
	Feed rate,t/h:	1.82
	Feed Size,Mesh:	-10+100

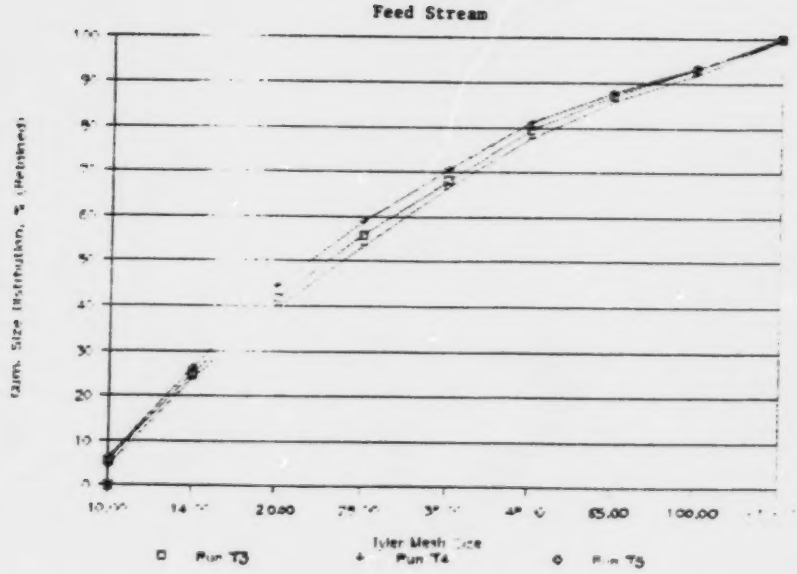
A. System : FEED = CONCENTRATE + MIDDLING + TAIL

			Weight and XRF analysis			
	&Feed1	*Feed2	Conc.	Mid.	Tail	Dust & Spillage
Weight kg	1650.00	1299.00	188.00	737.00	374.00	351.00
Yield %		100.00	14.5	56.7	28.8	
Kcl %	44.01	43.37	72.48	51.17	13.35	
Nacl %	50.96	52.21	22.42	43.35	84.64	
Insol %	3.52	3.31	3.72	4.05	1.65	
Carn. %	0.50≤	0.50≤	0.50≤	0.50≤	0.50≤	
		%	R E C O V E R Y			
Kcl		100.00	24.19	66.95	8.86	
Nacl		100.00	6.21	47.11	46.68	
Insol		100.00	16.26	69.39	14.35	
Carn.		100.00	14.47	56.74	28.79	

B. System : FEED = CONCENTRATION + TAIL

		Data calculated by combining conc.& middling as new CONCENTRATE		Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.0	71.2	28.8	14.5	85.5
Kcl %	43.37	55.50	13.35	72.48	38.44
Nacl %	52.21	39.10	84.64	22.42	57.25
Insol %	3.31	3.98	1.65	3.72	3.24
Carn. %	0.50≤	0.50≤	0.50≤	0.50≤	0.50≤
Kcl Recovery %		91.14	8.86	24.19	75.81
Separation Eff. %		35.19		17.16	

&Feed1 = Original feed
*Feed2 = Free-fall feed



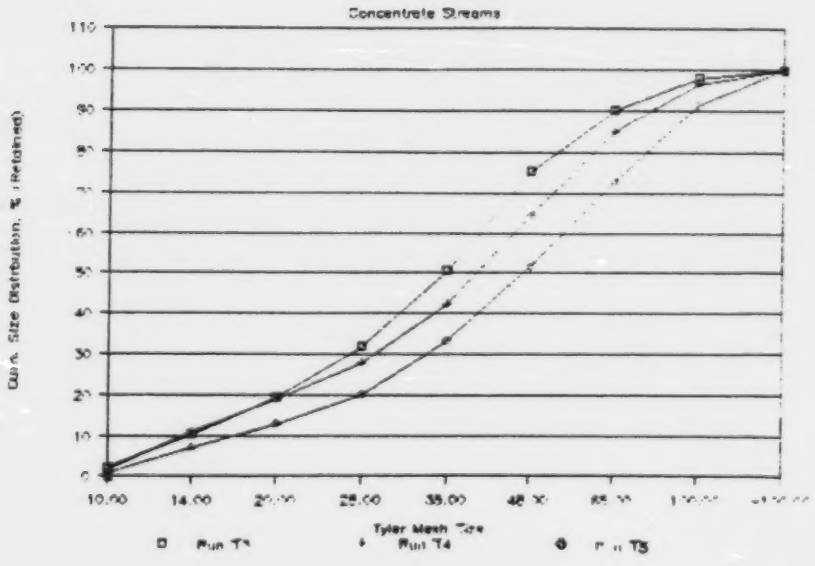


Fig. 20. PCS tube separator - comparison of particle size distributions of feed, concentrate streams of runs T3, T4 and T5.

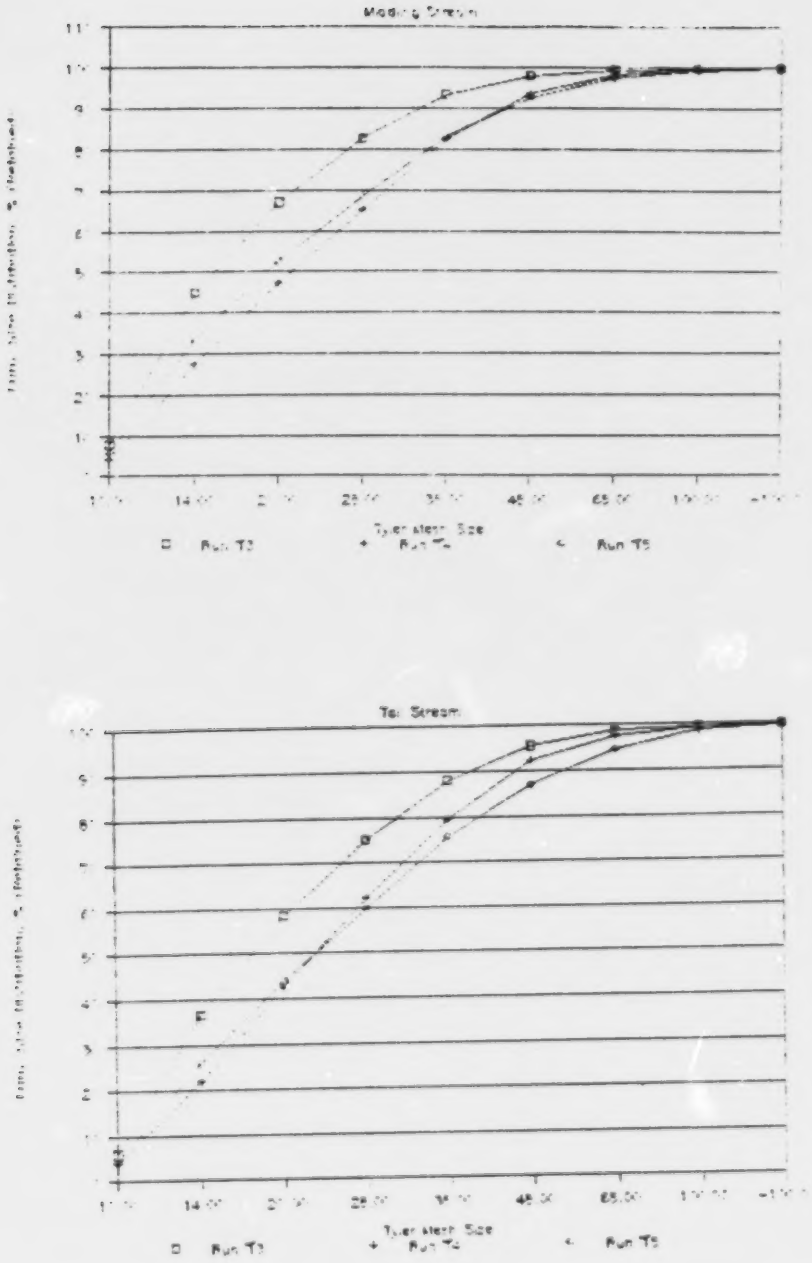


Fig. 21. PCS tube separator - comparison of particle size distribution of middling and tail streams of runs T3, T4 and T5.

TABLE 14. PCS Tube Free-fall Separator - Summary of Set Tube I Test Results

Run #	% KCl			%	Mean particle size mm			
	Feed	Conc.	Tail	Sep.eff	Feed	Conc.	Mid.	Tail
T3	49.43	60.3	26.5	31.9	0.8	0.58	1.10	1.01
T4	45.17	52.8	24.7	23.2	0.8	0.54	1.11	0.84
T5	43.37	55.5	13.4	35.2	0.8	0.45	1.18	0.85

Visual observation showed that the fluidization quality of run T3 was very good and because the 27.9 cm buffer plates were used, the bed was deep and ore particles had to squeeze through the dense and crowded environment prior to lifting up or sinking down. Therefore, coarser particles might result in a better charge and more coarse particles appearing in the concentrate and tail stream.

3.2.1.2 Effect of Electrode Height

The effect of electrode height on run T4 as shown in Table 14, was very obvious. The 33% short electrode of run T4 resulted in about 27% lower separation efficiency than that of run T3; the mean particle size of concentrate and tail stream was also finer than that of run T3.

3.3 Continuous Two-pass Operation

Two-pass continuous pilot runs were designed to gain new operation experience and knowledge of the effect and behavior of recycling streams in the first-pass and second-pass(2), charge relaxation, and fluidization in the second-pass fluidized bed, so that an appropriate operation circuit could be designed.

3.3.1 Two-pass Continuous Process with Recycle, -8 mesh Cory Feedstock

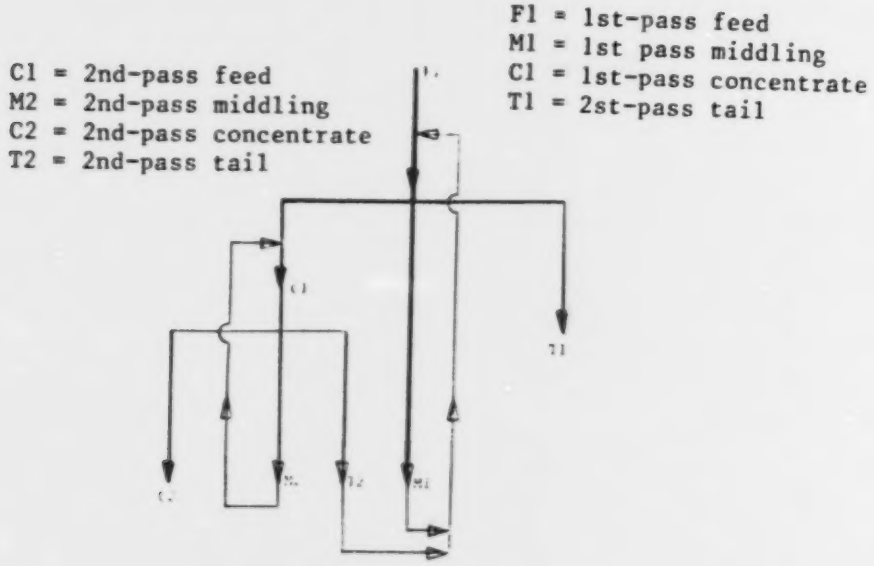

F1 = 1st-pass feed
M1 = 1st pass middling
C1 = 1st-pass concentrate
T1 = 2st-pass tail
C1 = 2nd-pass feed
M2 = 2nd-pass middling
C2 = 2nd-pass concentrate
T2 = 2nd-pass tail

Figure 22. Two-pass continuous process with recycling.

Figures 11 and 22 depict the two-pass continuous circuit with recycles: M1, the first-pass middling stream, and T2, the second-pass tail stream, were recycled back to a new feed stream, F1, while M2, the second-pass middling stream, was returned to the second-pass feed stream, C1. Set Tube-II test conditions and results of five pilot runs (#SP1, SP2, SP3, SP4 and SP5) with -8 mesh Cory feedstock are summarized in Table 15. Octanoic acid was used in runs SP1, SP2, SP3 and SP5 while Oleic acid was used in run SP3. Run time was about 30 to 40 minutes and samples of F1, C2, and T1 streams were taken at 5 to 15 minutes intervals for XRF, while composite samples were used for sieve analysis.

3.3.2 Effect of Recycle Stream

The effect of the recycle stream at the first pass was significant and occurred almost 10 minutes after the process started. As experienced in both plate and tube free-fall separators with single-pass operation, the yield of the first-pass middling stream, M1, was high (about 50-60%) and the particle size was coarser than that of feed F1. In the two-pass operation the two recycle streams, the

first-pass middling stream, M1, and the second-pass tail stream, T2, joining the fresh feed F1, increased loading with coarser feed to the primary fluidized bed. Therefore, at each free-fall processing only the fine and the medium-coarse particles were separated, leaving more and more coarse particles in the middling stream M1 recycled back to the fluidized bed.

The particle size of "free-fall" feed became coarser and coarser as the separation process went on and the M1 stream build-up increased steadily at about 85 kg/hr/min as shown in Fig. 23. The double effects of M1 build-up and coarser particle size distribution demanding higher and higher air flow capacity to fluidize the coarser particle size distribution and heavier loaded fluidized bed were noticeable.

At about 35 minutes operation time, the fluidized bed was choked and the fresh feed was cut off. The separation process reached an equilibrium state where there was little or no separation at all while almost the same feed was circulating through the free-fall separator. Fig. 23 also compared the pilot runs operating with or without the effect of the recycling of the middling stream, M1.

Some interesting results obtained from two-pass free-fall separation with recycle appeared as follows:

1. There was almost a 20% loss in the fine particle fraction (-65 mesh) at the three states of fluidization: (a) the fluidized bed dryer where the crushed ore shipped from Cory Division was dried, (b) the first-pass fluidized bed, and (c) the second-pass fluidized bed.

2. It seems that more insol followed the concentrate streams for both Octanoic acid and Oleic acid reagents. A similar finding appeared in the plate separator.

3. The average recovery and separation efficiency of the first three runs (SP1, SP2 and SP3) was about 60% and 34.6% respectively.

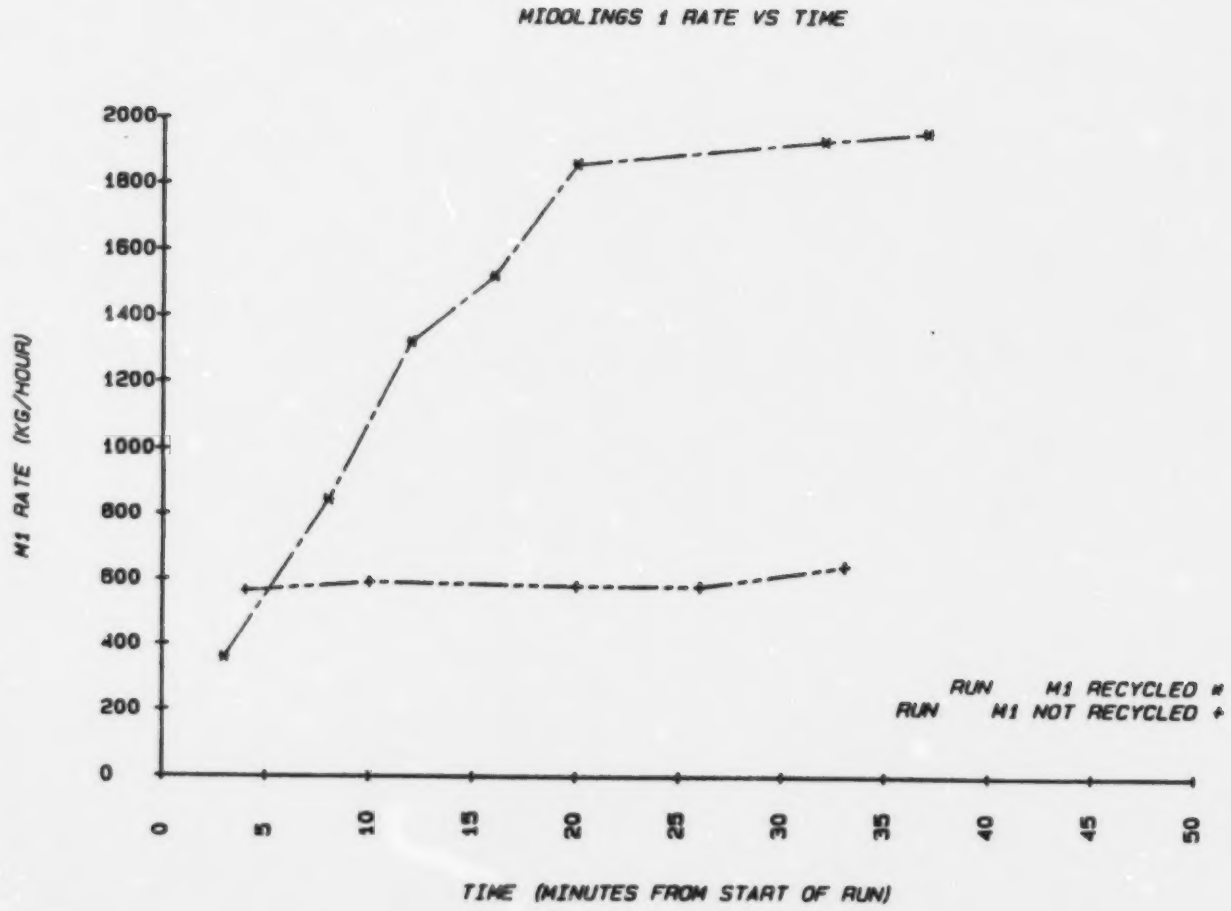


Figure 23 Comparison of built-up with and without middling recycle

Table 15 . PCS Tube free-fall separator - Summary of set tube-II test conditions and results

Operation parameters - Feed : - 8 Mesh Cory feedstock
% RH : < 9
HV : 45 Kv
Mode : Two-pass continuous

Run	% Grade	Feed Comp	Conc.	Tail	Yield	Recv.	Sep.Eff.	Reagent	feed rate.tph
	Kcl	41.96	61.96	29.33	38.71	57.16	31.79	0.A.	1.6
Sp1	Nacl	52.51	33.24	65.22					
	Insol	3.05	3.83	2.21					
	Carn.	0.50 ≤	0.50 ≤	0.50 ≤					

Run	% Grade	Feed Comp	Conc.	Tail	Yield	Recv.	Sep.Eff.	Reagent	feed rate.tph
	Kcl	42.50	62.62	26.88	43.70	64.39	35.98	0.A.	1.8
Sp2	Nacl	51.71	29.94	67.33					
	Insol	3.55	4.04	2.18					
	Carn.	0.50 ≤	0.50 ≤	0.50 ≤					

Run	% Grade	Feed Comp	Conc.	Tail	Yield	Recv.	Sep.Eff.	Reagent	feed rate.tph
	Kcl	41.96	63.95	27.39	39.65	60.74	35.98	01.A.	1.8
Sp3	Nacl	52.51	29.99	67.24					
	Insol	3.05	4.12	2.15					
	Carn.	0.50 ≤	0.50 ≤	0.50 ≤					

Run	% Grade	Feed Comp	Conc.	Tail	Yield	Recv.	Sep.Eff.	Reagent	feed rate.tph
	Kcl	46.45	77.78	23.43	42.36	70.92	53.35	0.A.	1.0
Sp4	Nacl	52.19	16.95	71.07					
	Insol	2.73	2.92	2.49					
	Carn.	0.50 ≤	0.50 ≤	0.50 ≤					

Run	% Grade	Feed Comp	Conc.	Tail	Yield	Recv.	Sep.Eff.	Reagent	feed rate.tph
	Kcl	34.42	62.42	25.64	23.87	43.29	29.61	0.A.	1.0
Sp5	Nacl	60.88	29.67	69.21					
	Insol	2.47	4.96	2.07					
	Carn.	0.50 ≤	0.50 ≤	0.50 ≤					

Due to finer feedstock particle size (Fig.29) and lower feed rate the separation efficiency and recovery of run SP4 appeared significantly better than those of runs SP1, SP2 and SP3. There was little or no difference in performance between octanoic acid and oleic acid.

4. In run SP5, the feedstock was a mixture of the tail streams of the savings from runs SP1, SP2 and SP3 and was kept overnight prior to separation. The runs were carried out to get some practical idea of whether the post-separation ore could be reprocessed without adding any additional reagent. Results appeared that although some extent of separation occurred, however the yield was low which indicated that particle charge had been depleted during the long storage hours.

3.3.3 Two-pass Continuous Process with Recycle, -10+65 mesh Rocanville Feed

Set Tube-III consisted of three runs (R1, R2 and R3) with octanoic acid and -10+65 mesh Rocanville ore, which has much lower insol content and was found in our early work to be more favorable to the ES process than the high insol Cory ore. The -65 mesh was screened off to reduce dust as a result of the experience of set Tube-II. Pilot run conditions and results are summarized in Table 16. Particle size distribution of the eight process streams, namely F1, F2, C1, C2, M1, M2, T1 and T2 of the three runs are illustrated by Fig. 24.

Regardless of the grade (KCl = 30%) of Rocanville feedstock (runs R1, R2, R3 and Table 6), it is 12% lower than that of Cory feedstock (KCl = 42.1%). Data of Tables 5 and 6 show that the nearly insol-free Rocanville feedstock results in nearly 47% separation efficiency which is about 12% better than that of clay-bearing Cory feedstock. However, recovery was still unacceptable (approximately 60%) because of the high yield in the middling stream, M1, as it was discussed in 3.3.1.

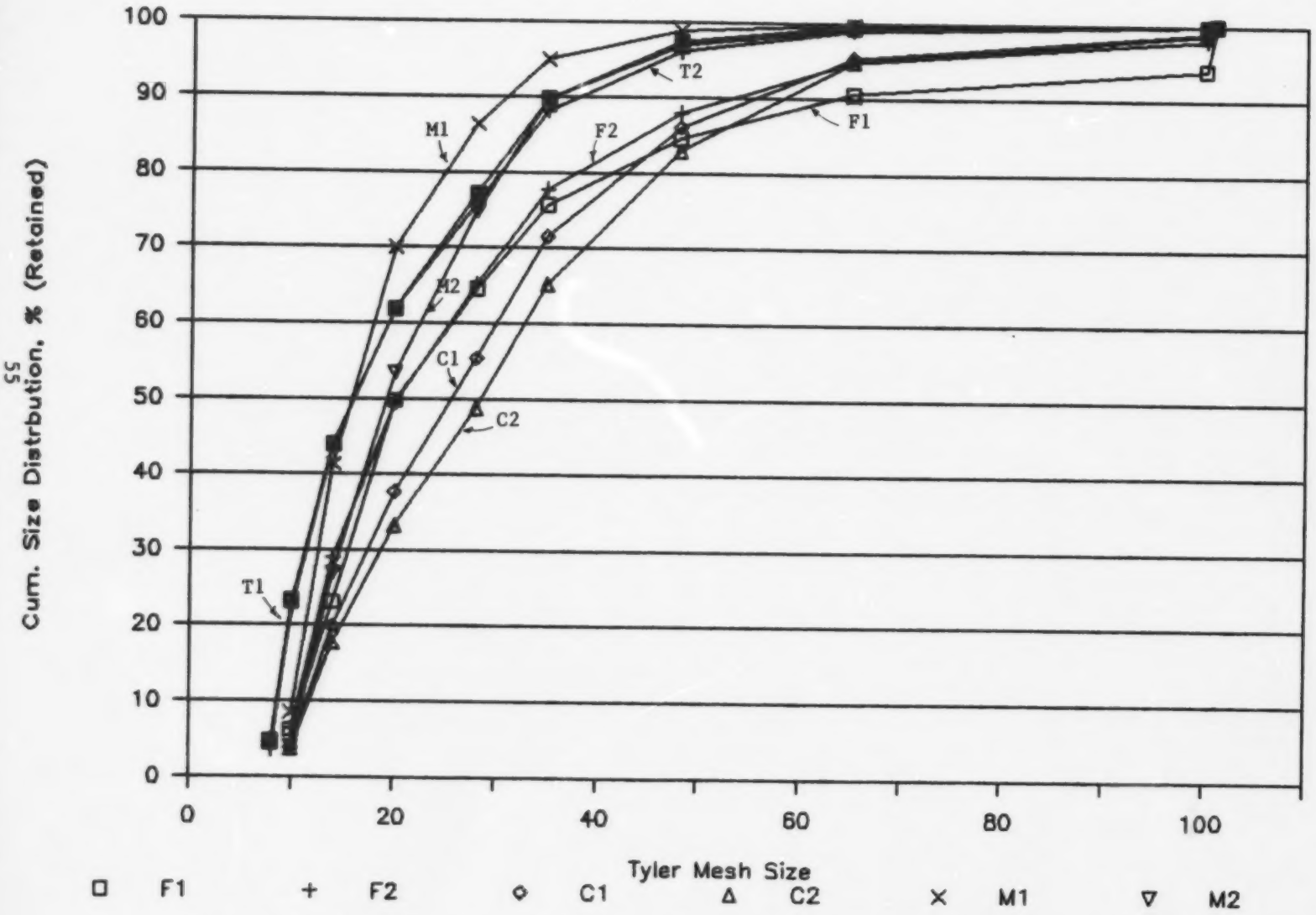


Figure 24. Particle size distribution of process streams F1, F2, C1 C2, M1, M2, T1 and T2 in two-pass continuous operation with Rocanville feedstock

Table 16. PCS tube free-fall separator - summary of set Tube-III test tube conditions and results

Operation parameters - Feed:Rocanville(-10+65 mesh)
Reagent : Octanoic acid
% RH : < 9
HV : 45 Kv
Mode : Two-pass continuous

* Run # R1 (Feed rate : 1.8 tph)

% Grade	Feed Comp	Conc.	Tail	Yield	Recv.	Sep.Eff.
Kcl	28.35	68.51	15.75	23.88	57.71	47.22
Nacl	68.44	27.85	80.33			
Insol	0.55	1.24	0.71			
Carn.	2.30	3.76	2.12			

* Run # R2 (Feed rate : 1.0 tph)

% Grade	Feed Comp	Conc.	Tail	Yield	Recv.	Sep.Eff.
Kcl	29.87	71.89	17.06	23.36	56.23	46.86
Nacl	66.70	24.70	79.35			
Insol	0.59	0.55	0.50			
Carn.	2.42	3.54	2.01			

* Run # R3 (Feed rate : 1.0 tph)

% Grade	Feed Comp	Conc.	Tail	Yield	Recv.	Sep.Eff.
Kcl	30.85	69.47	17.49	25.70	57.88	46.53
Nacl	66.08	27.32	79.38			
Insol	0.61	0.49	0.51			
Carn.	2.47	3.13	1.99			

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

This report presents the results of a pilot study on electrostatic beneficiation of potash ore by two free-fall separators. The batch and continuous processes are described and data are discussed. As there are no less than ten vital process parameters which affect the separation efficiency, as well as the constraint of time, only important parameters such as charging time, charging temperature, electrode height, feedstock particle size, reagents and recycle, were investigated. Conclusions can be summarized as follows:

1. Separation mechanism - Under a well controlled environment of temperature and humidity, potash (KCl) was charged negatively while salt (NaCl) was charged positively. The positively charged NaCl and negatively charged KCl particles were deflected toward negative and positive electrodes respectively, while free-falling in a uniform electric field where NaCl and KCl were separated (Figure 16). Finer particles can be deflected up to 40 cm from the free-fall centre line.

2. Temperature - With clay-bearing Cory Division feedstock, the separation efficiency appeared favourable at the condition near 60°C for both 2 and 6 minute charging time for octanoic acid, oleic acid and salicylic acid regardless of the difference in feedstock particle size and separator used. The University of Western Ontario data(5) also found the optimum for the ES process of stage 1 was approximately 50°C.

3. Charging time - With clay-bearing Cory Division feedstock, the separation efficiency peaked at about 6 minutes charging time for oleic acid, salicylic acid and ammonium acetate. Longer charging might not be favourable, as charging increased with time to a maximum and then decreased to an equilibrium level.

4. Feedstock particle size - With clay-bearing Cory Division feedstock, the finer feedstock (-14+100 mesh instead of -10+100 mesh) improved the separation efficiency significantly to nearly three times that of octanoic acid.

5. Electrode height - The effect of electrode height on separation efficiency and particle size in concentrate and tailings streams was significant. A 33% shorter electrode could result in 27% poorer separation efficiency and finer concentrate/ tailing.

6. Reagents - None of the four reagents had the capability to charge the fine clay particles selectively positive as happens with halide, so that clay/halide can be separated together to the tails stream. The insol content appeared more in the concentrate stream than that of the tailing, which is also reported elsewhere (4).

7. Recycle - The adverse effect of recycling the middling stream in the first-pass operation was identified. The excessive coarse particles in the middling stream are due to the charge and mass ratio, Q/M, of particles reached in its limited-value under a set of operation parameters. The deflection distance of the particle by the uniform field strength now becomes shorter to fall out the middle width because of heavier particle mass. Results suggest that the band width of the middling stream be narrowed down to cut off the % yield of the middling stream from the current 50-60% to about 35%, the concentrate and tailings would then go to the second-pass separation separately, while the coarse middling stream would be reground and returned as new feed.

8. Two-pass continuous beneficiation - For insol-bearing -8 mesh Cory Division feedstock, separation efficiency was about 36% and recovery 60%, while the separation efficiency of the nearly insol-free -10+100 mesh Rocanville Division feedstock was about 46%, 10% better than that of the insol-bearing Cory feedstock, and the recovery was about 57%.

To have a better idea of where the PCS electrostatic separator stands, Table 17 was compiled for ease of comparison. There were no process details for the West German data; however, from the grade of the final concentrate, it appeared that the process was not designed to produce the highest possible purity (95% KCl) product; but was rather, in some mills, for pre-concentration to electrostatically separate the bulk of halite prior to conventional wet processing through either hot dissolution or flotation (10).

Table 17. Comparison of Free-fall Separators between PCS and West Germany

Separator Configuration	This work		West Germany(9)
Separator long, m	2		40
Separator height, m	5.4 (effective electrode height)		46
Capacity t/m/h	Approx. 8.5		30
Reagent	Octanoic/oleic acid for Cory's runs Octanoic acid for Rocanville's runs		Trichloroacetic or salicylic acid
High tension kv/cm	2-3		4
Treatment temp. °C	Approx. 40		70-160
Particle size	-8 mesh and -10+100 mesh		Up to 1.5 mm (approx.10 mesh)
Feed grade	Cory*	Rocanville**	
%KCl	42.14	29.69	14.80
% Carnallite	0.5	2.39	7.60
% $MgSO_4$ H_2O	-	-	17.10
% NaCl	52.20	67.10	61.20
% Water Insoluble	3.21	0.58	NA
Final concentrate	Two-pass with recycle		NA
% KCl	62.84	69.95	28.5-31.66
% Recovery	60.7	57.3	67-92
% $MgSO_4$	-	-	21-43
% Recovery	-	-	74-97
% KCl	27.39 in tail stream	16.77 in tail stream	2.5-4.4 at 4% of total
Separation efficiency	34.58	46.90	52.20***

* Average of runs SP1, SP2 and SP3
** Average of runs R1, R2 and R3
*** Assumed 4% KCl in tail stream

Regardless of the significant difference between the West German's full scale commercial installation and the PCS pilot scale in throughput capacity, electrode height and operation temperature to feedstocks, Table 17, gives us an idea of where the PCS separator stands. The separation efficiency of West Germany's data which was calculated with the assumption that there was 4% KCl in the tail stream, is slightly better than that of Rocanville feedstock. One of the factors causing the low throughput and recovery of the PCS separator compared with West Germany's, is the electrode height; others can be caused by the width of the middling band, reagents and recycle circuit.

4.2 Recommendation

1. Electrode configuration - At least one set of experiments should be performed to investigate the effect of other electrode configurations on separation efficiency at 60°C and 5-6 minutes charging time.

2. Low insol-content feedstock - The effect of insol on separation is significant, but has not been systematically studied yet. At least two sets of experiments should be conducted with 1-2% and 2-3% insol-content feedstocks which can be prepared by pre-processing the feedstock with a magnetic separator.

3. Optimum middling band width - Additional experiments should be conducted to determine the optimum width of middlings.

4. Mechanisms of interaction between reagent and ore particulate leading to charge developing and retaining are the most important, and yet the least understood, in the electrostatic separation process. Techniques which used to evaluate reagent performance by measuring surface angle liquid droplets on KCl/NaCl surface, adsorption of reagents on to potash ore, and quantified charged accumulation of reagentized particles

colliding while falling down a dropping chute with a Faraday pail, have recently been reported. Yet new techniques such as gas chromatography using trace (reagent) injection methods for determining adsorption equilibrium constants, rate constants and interparticle diffusivities, or other techniques, need to be developed. A successful technique can then be used as a routine analysis mean for reagent evaluation prior to separation experiments.

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APPENDIX 1

TABLES P2 - P22

Table P2 . PCS Plate free-fall separator-Run # P2

Parameters		
	Reagent 1g/10kg:	Octanoic acid
	Temperature C:	60.00
	Humidity % :	12.00
	Charging time s :	120.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

Weight and XRF analysis

	Feed1 fluid-bed	Feed2 free-fall	Conc.	Mid.	Tail	Dust
Weight kg	10.00	8.03	1.67	4.45	1.91	1.97
Yield,%		100.00	20.80	55.42	23.79	
Kcl %	34.15	35.69	45.30	37.45	23.18	
Nacl %	54.42	55.09	43.47	54.64	66.29	
Insol %	6.10	5.30	7.33	4.32	5.81	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% R E C O V E R Y				
Kcl		100.00	26.40	58.15	15.45	
Nacl		100.00	16.41	54.97	28.62	
Insol		100.00	28.76	45.17	26.07	
Carn.		100.00	20.80	55.42	23.79	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	76.21	23.79	20.80	79.20
Kcl %	35.69	39.59	23.18	45.30	33.16
Nacl %	55.09	51.59	66.29	43.47	58.14
Insol %	5.30	5.14	5.81	7.33	4.77
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		84.55	15.45	26.40	73.60
Separation Eff. %		12.96		8.71	

* Feed2 = free-fall feed

Table p3 . PCS Plate free-fall separator-Run P3

Parameters		
	Reagent 1g/10kg:	Octanoic acid
	Temperature C:	80.00
	Humidity % :	12.00
	Charging time s :	300.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.33	1.82	6.14	1.37	0.68
Wt. %		100.00	19.51	65.81	14.68	
Kcl %	34.15	36.59	47.75	36.87	20.53	
Nacl %	54.42	53.64	39.02	54.21	70.51	
Insol %	6.10	5.22	6.95	4.50	6.14	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% R E C O V E R Y				
Kcl		100.00	25.45	66.31	8.24	
Nacl		100.00	14.19	66.51	19.30	
Insol		100.00	25.98	56.75	17.28	
Carn.		100.00	19.51	65.81	14.68	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	85.32	14.68	19.51	80.49
Kcl %	36.59	39.36	20.53	47.75	33.89
Nacl %	53.64	50.74	70.51	39.02	57.18
Insol %	5.22	5.06	6.14	6.95	4.80
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		91.76	8.24	25.45	74.55
Separation Eff. %		10.17		9.38	

* Free2 = free-fall feed

Table p4. PCS Plate Separator-Run # P4

Parameters		
	Reagent 1g/10kg:	Oleic acid
	Temperature C:	30.00
	Humidity % :	17.00
	Charging time s :	120.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	8.36	3.05	2.13	3.19	1.64
Yield %		100.00	36.48	25.48	38.04	
Kcl %	34.15	35.69	36.81	37.69	33.27	
Nacl %	54.42	55.07	52.72	54.81	57.49	
Insol %	6.10	5.73	6.64	4.44	5.71	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% R E C O V E R Y				
Kcl		100.00	37.63	26.91	35.46	
Nacl		100.00	34.93	25.36	39.71	
Insol		100.00	42.31	19.76	37.93	
Carn.		100.00	36.48	25.48	38.04	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	61.96	38.04	36.48	63.52
Kcl %	35.69	37.17	33.27	36.81	35.04
Nacl %	55.07	53.58	57.49	52.72	56.41
Insol %	5.73	5.74	5.71	6.64	5.20
Carn. %	0.50	0.50	0.50	0.50	0.50
Recovery %		64.54	35.46	37.63	62.37
Separation Eff. %		4.01		1.78	

*Feed2 = Free-fall feed

Table P5 . PCS Plate Separator-Run # P5

Parameters		
	<	Reagent 10g/10kg: Oleic acid
	<	Temperature C: 60.00
	<	Humidity % : 14.00
	<	Charging time s : 120.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.00	1.80	5.14	2.06	1.00
Yield %		100.00	20.00	57.11	22.89	
Kcl %	34.15	35.80	48.39	37.69	20.08	
Nacl %	54.42	55.31	40.19	54.81	69.76	
Insol %	6.10	5.36	8.00	4.44	5.33	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% R E C O V E R Y				
Kcl		100.00	27.03	60.13	12.84	
Nacl		100.00	14.53	56.60	28.87	
Insol		100.00	29.87	47.35	22.78	
Carn.		100.00	20.00	57.11	22.89	

B. System : FEED = CONCENTRATION + TAIL

		Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
		Feed	Conc.	Tail	Conc.	Tail
Wt. Yield	%	100.00	77.11	22.89	20.00	80.00
Kcl	%	35.80	40.47	20.08	48.39	32.65
Nacl	%	55.31	51.02	69.76	40.19	59.09
Insol	%	5.36	5.36	5.33	8.00	4.69
Carn.	%	0.50	0.50	0.50	0.50	0.50
Recovery	%		87.16	12.84	27.03	72.97
Separation Eff.	%		15.65		10.96	

*Feed2 = Free-fall feed

Table P6 . PCS Plate Separator-Run # P6

Parameters		
	Reagent 1g/10kg:	Oleic acid
	Temperature C:	80.00
	Humidity % :	14.00
	Charging time s :	300.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.16	1.41	5.69	2.06	0.84
Yield %		100.00	15.39	62.12	22.49	
Kcl %	34.15	35.86	44.21	37.97	24.31	
Nacl %	54.42	55.50	44.48	54.74	65.12	
Insol %	6.10	5.27	7.53	4.46	5.98	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% R E C O V E R Y				
Kcl		100.00	18.98	65.78	15.25	
Nacl		100.00	12.34	61.27	26.39	
Insol		100.00	21.98	52.53	25.50	
Carn.		100.00	15.39	62.12	22.49	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	77.51	22.49	15.39	84.61
Kcl %	35.86	39.21	24.31	44.21	34.34
Nacl %	55.50	52.70	65.12	44.48	57.50
Insol %	5.27	5.07	5.98	7.53	4.86
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		84.75	15.25	18.98	81.02
Separation Eff. %		11.29		5.59	

*Feed2 = Free-fall feed

Table P7 . PCS Plate Separator Run # P7

Parameters	Reagent 10g/10kg:Slicylic acid
	Temperature C: 30.00
	Humidity % : 14.00
	Charging time s : 120.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.08	2.75	4.13	2.21	0.92
Yield %		100.00	30.29	45.48	24.23	
Kcl %	34.15	35.04	38.69	33.22	33.89	
Nacl %	54.42	53.46	50.77	59.40	45.67	
Insol %	6.10	5.53	6.45	4.63	6.06	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		%	R E C O V E R Y			
Kcl		100.00	33.44	43.12	23.43	
Nacl		100.00	28.76	50.54	20.70	
Insol		100.00	35.34	38.10	26.56	
Carn.		100.00	30.29	45.48	24.23	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	75.77	24.23	30.29	69.71
Kcl %	35.04	35.41	24.03	48.39	33.45
Nacl %	53.46	55.95	65.79	40.19	54.63
Insol %	5.53	5.36	5.79	8.00	5.13
Carn. %	0.50	0.50	0.50	0.50	0.50
Recovery %		76.57	23.43	41.83	58.17
Separation Eff. %		1.56		6.23	

*Feed2 = Free-fall feed

Table P8 . PCS Plate Separator-Run # P8

Parameters		
	Reagent 10g/10kg:	Salicylic acid
	Temperature C:	60.00
	Humidity % :	14.00
	Charging time s :	120.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.27	1.53	6.72	1.03	0.73
Yield %		100.00	16.50	72.38	11.11	
Kcl %	34.15	36.36	50.02	36.07	17.99	
Nacl %	54.42	52.84	37.35	53.87	69.10	
Insol %	6.10	5.47	7.85	4.72	6.82	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		%	R E C O V E R Y			
Kcl		100.00	22.70	71.80	5.50	
Nacl		100.00	11.67	73.80	14.53	
Insol		100.00	23.69	62.46	13.85	
Carn.		100.00	16.50	72.38	11.11	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	88.89	11.11	16.50	83.50
Kcl %	36.36	38.66	17.99	50.02	33.66
Nacl %	52.84	50.80	69.10	37.35	55.90
Insol %	5.47	5.30	6.82	7.85	5.00
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		94.50	5.50	22.70	77.30
Separation Eff. %		8.82		9.74	

*feed2 = Free-fall feed

Table p9. PCS Plate Separator-Run # P9

Parameters		
	Reagent 10g/10kg:	Salicylic acid
	Temperature C:	80.00
	Humidity % :	14.00
	Charging time s :	300.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.32	1.25	7.23	0.84	0.68
Yield %		100.00	13.41	77.58	9.01	
Kcl %	34.15	36.00	49.74	35.71	18.00	
Nacl %	54.42	54.35	39.92	54.87	71.30	
Insol %	6.10	5.57	7.22	5.28	5.56	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% R E C O V E R Y				
Kcl		100.00	18.53	76.96	4.51	
Nacl		100.00	9.85	78.32	11.82	
Insol		100.00	17.40	73.60	9.00	
Carn.		100.00	13.41	77.58	9.01	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	90.99	9.01	13.41	86.59
Kcl %	36.00	37.78	18.00	49.74	33.87
Nacl %	54.35	52.67	71.30	39.92	56.58
Insol %	5.57	5.57	5.56	7.22	5.31
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		95.49	4.51	18.53	81.47
Separation Eff. %		7.04		8.00	

*Feed2 = Free-fall feed

Table P10. PCS Plate Separator-Run # P10

Parameters		
	Reagent 10g/10kg:	Ammonium acetate
	Temperature C:	30.00
	Humidity % :	12.00
	Charging time s :	120.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	8.98	1.25	6.80	0.93	1.01
Yield %		100.00	13.92	75.72	10.36	
Kcl %	34.15	36.02	43.00	35.11	33.28	
Nacl %	54.42	56.62	47.54	58.20	57.23	
Insol %	6.10	4.14	6.08	3.62	5.36	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% R E C O V E R Y				
Kcl		100.00	16.62	73.81	9.57	
Nacl		100.00	11.69	77.84	10.47	
Insol		100.00	20.43	66.17	13.40	
Carn.		100.00	13.92	75.72	10.36	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	89.64	10.36	13.92	86.08
Kcl %	36.02	36.34	33.28	43.00	34.89
Nacl %	56.62	56.54	57.23	47.54	58.08
Insol %	4.14	4.00	5.36	6.08	3.83
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		90.43	9.57	16.62	83.38
Separation Eff. %		1.23		4.22	

*Feed2 = Free-fall feed

Table P11. PCS Plate Separator-Run # P11

Parameters		
	<	Reagent 10g/10kg: Ammonium acetate
	<	Temperature C: 60.00
	<	Humidity % : 12.00
	<	Charging time s : 120.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.20	1.04	7.26	0.90	0.79
Yield %		100.00	11.30	78.91	9.78	
Kcl %	34.15	36.72	58.14	35.79	19.43	
Nacl %	54.42	57.91	47.54	57.74	71.27	
Insol %	6.10	3.95	5.26	3.73	4.21	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% R E C O V E R Y				
Kcl		100.00	17.90	76.92	5.18	
Nacl		100.00	9.28	78.68	12.04	
Insol		100.00	15.05	74.52	10.43	
Carn.		100.00	11.30	78.91	9.78	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	90.22	9.78	11.30	88.70
Kcl %	36.72	38.59	19.43	58.14	33.99
Nacl %	57.91	56.46	71.27	47.54	59.23
Insol %	3.95	3.92	4.21	5.26	3.78
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		94.82	5.18	17.90	82.10
Separation Eff. %		7.28		10.42	

*Feed2 = Free-fall feed

Table P12. PCS Plate Separator-Run # P12

Parameters		
	Reagent 10g/10kg:	Ammonium acetate
	Temperature C:	80.00
	Humidity % :	12.00
	Charging time s :	300.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.16	0.99	7.34	0.83	0.75
Yield %		100.00	10.81	80.13	9.06	
Kcl %	34.15	36.60	60.90	35.82	14.46	
Nacl %	54.42	55.01	32.10	57.79	57.74	
Insol %	6.10	3.91	4.86	3.83	3.50	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		%	R E C O V E R Y			
Kcl		100.00	17.99	78.43	3.58	
Nacl		100.00	6.31	84.18	9.51	
Insol		100.00	13.43	78.46	8.11	
Carn.		100.00	10.81	80.13	9.06	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	90.94	9.06	10.81	89.19
Kcl %	36.60	38.80	14.46	60.90	33.65
Nacl %	55.01	54.74	57.74	32.10	57.78
Insol %	3.91	3.95	3.50	4.86	3.80
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		96.42	3.58	17.99	82.01
Separation Eff. %		8.64		11.32	

*Feed2 = Free-fall feed

Table p13. PCS Plate Separator-Run # P13

Parameters		
	Reagent 1g/10kg:	Octanoic acid
	Temperature C:	60.00
	Humidity % :	18.00
	Charging time s :	360.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.28	1.96	5.86	1.46	0.72
Yield %		100.00	21.09	63.16	15.75	
Kcl %	33.49	35.96	60.43	33.96	11.23	
Nacl %	59.77	58.46	33.00	61.09	82.02	
Insol %	3.93	3.19	3.87	3.04	2.90	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% R E C O V E R Y				
Kcl		100.00	35.44	59.64	4.92	
Nacl		100.00	11.91	66.00	22.09	
Insol		100.00	25.56	60.13	14.30	
Carn.		100.00	21.09	63.16	15.75	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	84.25	15.75	21.09	78.91
Kcl %	35.96	40.59	11.23	60.43	29.42
Nacl %	58.46	54.06	82.02	33.00	65.27
Insol %	3.19	3.25	2.90	3.87	3.01
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		95.08	4.92	35.44	64.56
Separation Eff. %		16.91		22.41	

*Feed2 = Free-fall feed

Table 14. PCS Plate Separator-Run # P14

Parameters		
	Reagent 1g/10kg:	Octanoic acid
	Temperature C:	60.00
	Humidity % :	17.00
	Charging time s :	600.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis				
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	8.45	1.53	4.73	2.18	1.55
Yield %		100.00	18.16	56.01	25.83	
Kcl %	33.49	35.18	56.88	37.85	14.12	
Nacl %	59.77	59.66	37.31	57.75	79.53	
Insol %	3.93	2.89	4.00	2.47	3.03	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% RECOVERY				
Kcl		100.00	29.36	60.27	10.37	
Nacl		100.00	11.35	54.22	34.43	
Insol		100.00	25.11	47.83	27.06	
Carn.		100.00	18.16	56.01	25.83	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE		Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	74.17	25.83	18.16	81.84
Kcl %	35.18	42.51	14.12	56.88	30.36
Nacl %	59.66	52.75	79.53	37.31	64.62
Insol %	2.89	2.84	3.03	4.00	2.65
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		89.63	10.37	29.36	70.64
Separation Eff. %		23.85		17.28	

*Feed2 = Free-fall feed

Table P15. PCS Plate Separator-Run # P15

Parameters		
	Reagent 1g/10kg:	Oleic acid
	Temperature C:	60.00
	Humidity % :	17.00
	Charging time s :	360.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis				
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.39	2.68	4.75	1.96	0.61
Yield %		100.00	28.56	50.57	20.87	
Kcl %	33.49	34.06	53.77	32.76	10.24	
Nacl %	59.77	61.02	40.75	63.02	83.92	
Insol %	3.93	3.02	3.83	2.81	2.42	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% R E C O V E R Y				
Kcl		100.00	45.08	48.64	6.27	
Nacl		100.00	19.07	52.23	28.70	
Insol		100.00	36.22	47.06	16.72	
Carn.		100.00	28.56	50.57	20.87	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	79.13	20.87	28.56	71.44
Kcl %	34.06	40.34	10.24	53.77	26.18
Nacl %	61.02	54.98	83.92	40.75	69.12
Insol %	3.02	3.18	2.42	3.83	2.70
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		93.73	6.27	45.08	54.92
Separation Eff. %		22.13		25.06	

*Feed2 = Free-fall feed

Table p16. PCS Plate Separator-Run # P16

Parameters		
	Reagent 1g/10kg:	Oleic acid
	Temperature C:	60.00
	Humidity % :	17.00
	Charging time s :	600.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.05	1.38	6.19	1.48	0.95
Wt. %		100.00	15.21	68.46	16.33	
Kcl %	33.49	36.15	48.85	37.86	17.15	
Nacl %	59.77	58.61	43.77	57.46	77.24	
Insol %	3.93	3.06	4.72	2.53	3.72	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		%	R E C O V E R Y			
Kcl		100.00	20.55	71.70	7.75	
Nacl		100.00	11.36	67.12	21.52	
Insol		100.00	23.48	56.65	19.87	
Carn.		100.00	15.21	68.46	16.33	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	83.67	16.33	15.21	84.79
Kcl %	36.15	39.86	17.15	48.85	33.87
Nacl %	58.61	54.97	77.24	43.77	61.27
Insol %	3.06	2.93	3.72	4.72	2.76
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		92.25	7.75	20.55	79.45
Separation Eff. %		13.44		8.37	

Note: Feed2 was the real feed dropped throught the separator

Table P17. PCS Plate Separator-Run # P17

Parameters	Reagent 10g/10kg:Ammonium acetate
	Temperature C: 60.00
	Humidity % : 15.00
	Charging time s : 360.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.18	1.51	5.55	2.11	0.82
Yield %		100.00	16.49	60.48	23.03	
Kcl %	33.49	35.96	54.28	39.22	14.27	
Nacl %	59.77	59.51	40.24	56.18	82.07	
Insol %	3.93	2.93	3.72	2.84	2.59	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		%	R E C O V E R Y			
Kcl		100.00	24.89	65.97	9.14	
Nacl		100.00	11.15	57.10	31.76	
Insol		100.00	20.95	58.68	20.37	
Carn.		100.00	16.49	60.48	23.03	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	76.97	23.03	16.49	83.51
Kcl %	35.96	42.45	14.27	54.28	32.34
Nacl %	59.51	52.77	82.07	40.24	63.32
Insol %	2.93	3.03	2.59	3.72	2.77
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		90.86	9.14	24.89	75.11
Separation Eff. %		21.69		13.12	

*Feed2 = Free-fall feed

Table P18. PCS Plate Separator-Run # P18

Parameters		
	< Reagent 10g/10kg:	Ammonium acetate
	< Temperature C:	60.00
	< Humidity % :	15.00
	< Charging time s :	600.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.47	0.86	7.23	1.38	0.53
Yield %		100.00	9.09	76.39	14.52	
Kcl %	33.49	38.55	51.86	40.79	18.42	
Nacl %	59.77	56.74	41.22	54.66	77.37	
Insol %	3.93	2.85	3.45	2.84	2.53	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% R E C O V E R Y				
Kcl		100.00	12.23	80.83	6.94	
Nacl		100.00	6.61	73.59	19.80	
Insol		100.00	11.01	76.11	12.89	
Carn.		100.00	9.09	76.39	14.52	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	85.48	14.52	9.09	90.91
Kcl %	38.55	41.97	18.42	51.86	37.22
Nacl %	56.74	53.23	77.37	41.22	58.29
Insol %	2.85	2.90	2.53	3.45	2.79
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		93.06	6.94	12.23	87.77
Separation Eff. %		12.34		5.11	

*Feed2 = Free-fall feed

Table p19. PCS Plate Separator-Run # P19

Parameters	Reagent 10g/10kg:	Salicylic acid
	Temperature C:	60.00
	Humidity % :	15.00
	Charging time s :	360.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
	Weight and XRF analysis					
Weight kg	10.00	9.10	1.95	5.68	1.48	0.90
Yield %		100.00	21.40	62.36	16.24	
Kcl %	33.49	38.79	53.18	41.25	10.36	
Nacl %	59.77	56.77	41.22	54.36	86.53	
Insol %	3.93	2.78	3.45	2.71	2.18	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		%	R E C O V E R Y			
Kcl		100.00	29.35	66.32	4.34	
Nacl		100.00	15.54	59.71	24.75	
Insol		100.00	26.54	60.74	12.72	
Carn.		100.00	21.40	62.36	16.24	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE Feed	Conc.	Tail	Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL Conc.	Tail
Wt. Yield %	100.00	83.76	16.24	21.40	78.60
Kcl %	38.79	44.30	10.36	53.18	34.87
Nacl %	56.77	51.00	86.53	41.22	61.01
Insol %	2.78	2.90	2.18	3.45	2.60
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		95.66	4.34	29.35	70.65
Separation Eff. %		19.44		12.98	

*Feed2 = Free-fall feed

Table P20. PCS Plate Separator-Run # P20

Parameters		
	Reagent 10g/10kg:	Salicylic acid
	Temperature C:	60.00
	Humidity % :	15.00
	Charging time s :	600.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis				
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	9.64	1.82	6.52	1.29	0.37
Yield %		100.00	18.91	67.71	13.38	
Kcl %	33.49	38.34	48.21	40.10	15.49	
Nacl %	59.77	57.33	47.24	55.36	81.60	
Insol %	3.93	2.69	2.85	2.76	2.14	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		%	R E C O V E R Y			
Kcl		100.00	23.78	70.82	5.40	
Nacl		100.00	15.58	65.38	19.04	
Insol		100.00	20.00	69.37	10.63	
Carn.		100.00	18.91	67.71	13.38	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	86.62	13.38	18.91	81.09
Kcl %	38.34	41.87	15.49	48.21	36.04
Nacl %	57.33	53.59	81.60	47.24	59.69
Insol %	2.69	2.78	2.14	2.85	2.66
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		94.60	5.40	23.78	76.22
Separation Eff. %		12.93		7.89	

*Feed2 = Free fall feed

Table P21. PCS Plate Separator-Run # P21

Parameters		
	Reagent 1g/10kg:	Octanoic acid
	Temperature C:	60.00
	Humidity % :	15.00
	Charging time s :	360.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	8.38	2.03	3.25	3.09	1.63
Yield %		100.00	24.29	38.85	36.86	
Kcl %	45.75	47.17	79.45	56.79	15.76	
Nacl %	49.70	49.46	17.80	39.70	80.62	
Insol %	3.21	2.40	1.91	2.53	2.58	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		% R E C O V E R Y				
Kcl		100.00	40.91	46.78	12.32	
Nacl		100.00	8.74	31.18	60.08	
Insol		100.00	19.35	40.99	39.66	
Carn.		100.00	24.29	38.85	36.86	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	63.14	36.86	24.29	75.71
Kcl %	47.17	65.51	15.76	79.45	36.82
Nacl %	49.46	31.28	80.62	17.80	59.62
Insol %	2.40	2.29	2.58	1.91	2.55
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		87.68	12.32	40.91	59.09
Separation Eff. %		46.46		31.46	

*Feed2 = Free-fall feed

Table P22. PCS Plate Separator-Run # P22

Parameters		
	Reagent 10g/10kg:	Ammonium acetate
	Temperature C:	60.00
	Humidity % :	15.00
	Charging time s :	360.00

A. System : FEED = CONCENTRATE + MIDDLING + TAIL

	Weight and XRF analysis					
	Feed1	*Feed2	Conc.	Mid.	Tail	Dust
Weight kg	10.00	8.56	1.50	3.76	3.30	1.44
Yield %		100.00	17.52	43.94	38.54	
Kcl %	45.75	46.49	71.37	53.66	27.01	
Nacl %	49.70	49.81	25.71	43.02	68.50	
Insol %	3.21	2.32	1.90	2.20	2.64	
Carn. %	0.50	0.50	0.50	0.50	0.50	
		%	R E C O V E R Y			
Kcl		100.00	26.89	50.72	22.39	
Nacl		100.00	9.04	37.96	53.00	
Insol		100.00	14.36	41.73	43.91	
Carn.		100.00	17.52	43.94	38.54	

B. System : FEED = CONCENTRATION + TAIL

	Option 1 (Fig.14b) Data calculated by combining conc.& middling as new CONCENTRATE			Option 2 (Fig.14c) Data calculated by combining tail & middling as new TAIL	
	Feed	Conc.	Tail	Conc.	Tail
Wt. Yield %	100.00	61.46	38.54	17.52	82.48
Kcl %	46.49	58.71	27.01	71.37	41.21
Nacl %	49.81	38.09	68.50	25.71	54.92
Insol %	2.32	2.11	2.64	1.90	2.41
Carn. %	0.50	0.50	0.50	0.50	0.50
Kcl Recovery %		77.61	22.39	26.89	73.11
Separation Eff. %		30.18		17.52	

*Feed2 = Free-fall feed

APPENDIX 2

X-RAY FLUORESCENCE

X-RAY FLUORESCENCE

In order to analyse anything by x-ray fluorescence, a calibration must be done using samples of the same composition and texture as the unknowns. Generally several samples are analysed chemically and these samples are used to set up an x-ray calibration.

For electrostatic separation samples, the samples are pulverized so that the majority of the particles are less than 100 mesh. The pulverized samples are then put into a "spec cap" which is 40 mm in diameter by 10 mm in depth, and pressed at 30,000 lbs of pressure on an automatic hydraulic pellet press. These samples are run on x-ray for intensity in counts per seconds and concentrations determined from the calibration set up as above. The carnallite is calculated from magnesium concentration obtained from x-ray.